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SEASONAL DEVELOPMENT, INSECT VECTORS, AND HOST RANGE OF BACTERIAL WILT OF SWEET CORN[1]

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INTRODUCTION

The work described in the present paper is a continuation of an investigation on bacterial wilt previously reported by the writers (*4*, *9*).[3] Cooperative investigations on the insect phases of this disease by the Division of Cereal Crops and Diseases, Bureau of Plant Industry, and the Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine, were begun in 1933 and concluded with the 1937 season. The results of the last three seasons are given here, in comparison with the first year's results, already published, and include further studies of the occurrence and distribution of bacterial wilt, of the insect vectors of this disease, and of the host range of the wilt organism (*Aplanobacter stewarti* (E. F. Smith) McC.[4]

BACTERIAL WILT ON CORN

WORK PRIOR TO 1934

A number of investigators during the past 40 years have contributed to the knowledge of seasonal development of bacterial wilt of corn (*Zea mays* L.), but consecutive records of the amount of wilt in any one locality over a long period of years are very limited. Rand and Cash (*10*) calculated total percentages of wilt for 1918–23 in relation to temperature and rainfall. No consecutive records of the accumulation and spread of wilt from 1923 to the present have been published. Haenseler[5] has given a general picture of the wilt situation in New Jersey since 1910, and estimated percentages of wilt in different localities are available in Government and State publications. The use of these figures and records in comparison with winter temperatures has led to the conclusion that there is a definite relationship between winter temperatures and wilt development.[6][7] Haenseler[6] reported that a certain time factor or lag period is involved and that after a period of severe wilt a single cold winter may not be sufficient to give the expected disease control, and likewise after a period of little wilt the first warm winter may not be sufficient to give a wilt outbreak the following summer. The desirability of more definite wilt records for the

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[3] Italic numbers in parentheses refer to Literature Cited, p. 686.

[4] Synonym, *Phytomonas stewarti* (E. F. Smith) Bergey et al.

[5] HAENSELER, C. M. CORRELATION BETWEEN WINTER TEMPERATURES AND INCIDENCE OF SWEET CORN WILT IN NEW JERSEY. U. S. Bur. Plant Indus., Plant Dis. Rptr. 21: 298–301. 1937. [Mimeographed.]

[6] HAENSELER, C. M. See footnote 5.

[7] STEVENS, N. E. STEWART'S DISEASE IN RELATION TO WINTER TEMPERATURE. U. S. Bur. Plant Indus., Plant Dis. Rptr. 18: 141–149. 1934. [Mimeographed.]

TABLE 1.—*Natural bacterial wilt infection on sweet corn at the Arlington Experiment Farm, Arlington, Va.*

RESISTANT VARIETIES

Variety and date planted	Date of record	Condition on date of record	Plants							Ears		
			Total	Infected		Showing indicated degree of infection[1]				Marketable	Weight	
						a	*b*	*c*	*d*			
1934			*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*No.*	*Kilograms*	*Grams*
Golden Cross Bantam:[2]												
May 9	June 14	10 inches	1,368	88	6.4				0.1			
	July 11	Tassel to silk	1,368	1,368	100.0	72.6	24.3	2.6	.5			
Large type Golden Bantam (open-pollinated):[2]												
May 1	July 3	Tassel	577	577	100.0	69.7	27.4	2.9	0			
Do	do	do	459	459	100.0	66.4	30.9	2.6	0			
May 15	July 23	do	689	689	100.0	46.3	40.6	12.0	1.0			
May 29	July 28	do	573	573	100.0	48.3	36.5	12.6	2.6			
June 12	Aug. 24	Roasting ear	636	636	100.0	59.9	26.6	8.2	5.3			
June 26	do	Tassel	547	547	100.0	71.4	16.6	3.7	8.2			
1935												
Golden Cross Bantam:[2]												
May 9	June 11	10 inches	468	43	9.2	.9	5.3	3.0	0	165	29	160
	July 15	Tassel to silk	491	349	71.1	57.6	13.2	.2	0			
May 15	June 24	10 inches	536	65	12.1	2.4	8.0	1.5	.2	173	27	125
	July 15	Tassel to silk	[4] 632	373	59.0	42.6	13.1	3.0	.3			
June 1	July 19	Tassel	570	197	34.6	19.1	11.4	2.8	1.2	157	24	600
June 15	July 20	20 inches	534	80	15.0	12.7	1.9	.4	0	134	23	300
July 1	July 25	10 inches	447	110	24.6	6.5	11.0	5.8	1.3	117	19	300
	Aug. 21	Tassel	578	404	69.9	64.4	4.7	0	.9			
July 15	Aug. 24	8 inches	342	105	30.7	17.0	3.2	.3	10.2	[5] 40	5	700
	Sept. 12	Silk	291	84	28.9	22.3	.7	0	5.8			
Aug. 1	Sept. 13	12 inches	273	76	27.8	0	0	0	27.8	0		
Total or average										786	129	185

1936												
Golden Cross Bantam: [3]												
May 7	June 15	10 inches	216	0	0	0	0	0	0			
	July 13	Tassel	214	7	3.3	2.3	.9	0	0	131	22	935
	Aug. 5	Harvested	214	160	74.8	73.8	.9	0	0			
May 21	June 29	10 inches	137	0	0	0	0	0	0			
	July 13	Beginning to tassel	132	2	1.5	.8	.8	0	0	89	14	775
	Aug. 5	Silk	132	103	78.0	65.2	12.9	0	0			
June 1	July 6	10 inches	223	1	.4	0	.4	0	0			
	Aug. 5	Silk	220	88	40.0	35.0	5.0	0	0	128	22	10
	Aug. 20	Harvested	220	110	50.0	49.1	.9	0	0			
June 15	July 13	10 inches	353	0	0	0	0	0	0			
	Aug. 5	Beginning to tassel	350	33	9.4	8.6	.9	0	0	152	29	515
	Aug. 20	Harvested	325	120	36.9	21.5	15.4	0	0			
July 1	Aug. 5	10 inches	308	17	5.5	4.9	.6	0	0			
	Aug. 26	Silk	299	293	98.0	83.9	13.4	.7	0	114	18	405
	Sept. 21	Harvested	299	299	100.0	0	99.3	.7	0			
July 15	Aug. 11	10 inches	305	2	.7	0	.7	0	0			
	Aug. 28	Tassel	298	203	68.1	53.7	11.7	2.7	0	64	9	425
	Sept. 9	Silk	296	294	99.3	66.2	31.4	1.7	0			
	Oct. 1	After harvest	294	294	100.0	10.2	86.4	.3	3.1			
Total or average										678	117	65
1937												
Golden Cross Bantam: [3]												
May 11	June 8	6–8 inches	291	22	7.6	.3	5.2	2.1	0			
	June 21	16 inches	286	29	10.1	.3	6.6	3.1	0	159	27	275
	July 16	Silk	286	266	93.0	86.4	5.9	.7	0			
May 17	June 21	16 inches	237	30	12.7	0	9.3	3.4	0	181	34	969
	July 17	Silk	239	232	97.1	81.2	15.9	0	0			
June 1	July 19	14–26 inches	237	222	93.7	88.2	5.1	.4	0			
	Aug. 2	Silk	238	238	100.0	52.9	45.8	1.3	0	161	27	975
June 14	July 17	10–12 inches	247	56	22.7	6.1	11.7	4.9	0			
	Aug. 10	Silk	244	244	100.0	63.9	32.4	3.7	0	123	23	680
July 1	...do	24 inches	279	245	87.8	59.1	20.1	8.6	0			
	Sept. 4	Silk	279	279	100.0	29.4	66.7	3.9	0	84	13	210
July 17	...do	18–24 inches	229	185	80.8	40.2	29.7	6.6	4.4			
	Sept. 16	Silk	229	222	96.9	61.6	18.8	8.7	4.8	5	0	630
Total or average										713	127	739

See footnotes at end of table.

TABLE 1.—*Natural bacterial wilt infection on sweet corn at the Arlington Experiment Farm, Arlington, Va.*—Continued

SUSCEPTIBLE VARIETIES

Variety and date planted	Date of record	Condition on date of record	Plants							Ears		
			Total	Infected		Showing indicated degree of infection [1]				Marketable	Weight	
						a	*b*	*c*	*d*			
1934												
Golden Bantam Inbred 8482-3-1: [2]			*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*No.*	*Kilograms*	*Grams*
May 9	June 14	10 inches	220	49	22.3							
	July 10	Tassel	359	359	100.0	24.0	29.8	20.1	26.2			
May 21	June 15		207	64	30.9				0			
	July 11	Tassel	207	207	100.0	23.2	12.6	19.8	44.4			
Golden Bantam (Maine seed):												
May 9	June 15	10 inches	343	220	64.1				0			
	July 11	Tassel	349	349	100.0	22.3	24.4	17.8	35.5			
Golden Bantam (Idaho seed):												
May 9	June 15	10 inches	468	400	85.5				0			
	July 11	Tassel	457	457	100.0	28.0	32.4	20.1	19.5			
1935												
Gill Bros. Improved Golden Bantam (Oregon seed):												
May 9	June 18	10 inches	427	246	57.6	6.8	22.3	22.5	6.1	30	3	200
	July 15	Tassel to silk	412	412	100.0	8.3	37.4	31.3	23.1			
May 15	June 24	10 inches	518	351	67.8	8.1	29.7	18.7	11.2			
	July 15	Tassel	462	456	98.7	16.7	27.9	37.9	16.2	27	2	8
June 1	July 19	do	436	427	97.9	19.0	25.5	29.6	23.9	18	2	100
June 15	July 20	12 inches	368	248	67.4	32.9	16.6	10.6	7.3	28	3	840
July 1	July 25	8 inches	303	264	87.1	1.3	31.4	28.1	26.4			
	Aug. 8	Tassel	236	222	94.1	7.2	22.5	35.2	29.2	5		500
July 15	Aug. 24	12 inches	246	170	69.1	10.2	.8	1.2	56.9			
	Sept. 12	Tassel	177	104	58.8	.6	0	0	58.2	[3] 0		
Aug. 1	Sept. 13	12 inches and tassel	267	101	37.8	0	0	.8	37.1	[3] 0		
Total or average										108	11	648

1936												
Gill Bros. Improved Golden Bantam (Oregon seed):												
May 7	June 15	10 inches	270	12	4.4	.4	2.9	1.1	0			
	June 29	Tassel	267	15	5.6	.4	4.1	.7	.4			
	July 13	Harvest	267	58	21.7	15.4	4.9	.7	.7	28	3	565
	Aug. 3	Drying	267	178	66.7	21.0	33.0	6.0	6.7			
May 21	July 6	6–12 inches	216	2	.9	0	.5	.5	0			
	July 13	Tassel	216	20	9.3	8.3	.9	0	0			
	Aug. 5	Harvest	216	182	84.3	39.4	40.3	3.2	1.4	67	8	420
June 1	July 6	6–12 inches	283	2	.7	0	.4	.4	0			
	July 13	Tassel	283	2	.7	.4	0	0	.4			
	Aug. 5	Silk	282	201	71.3	54.6	16.3	.4	0	103	14	240
June 15	July 13	4–10 inches	374	0	0	0	0	0	0			
	Aug. 5	Silk	374	109	29.1	21.4	5.3	2.1	.3			
	Aug. 26	Harvest	374	374	100.0	0	70.1	20.1	9.9	85	13	640
July 1	Aug. 5	6–12 inches	337	99	29.4	21.7	3.0	3.3	1.5			
		Silk to harvest	331	331	100.0	1.5	76.4	17.2	4.8	43	4	140
July 15	Aug. 11	5–10 inches	329	42	12.8	0	9.1	3.0	.6			
	Aug. 28	Tassel	329	318	96.7	25.2	35.9	24.6	10.9	0		
Total or average										326	44	5
1937												
Gill Bros. Improved Golden Bantam (Oregon seed):												
May 11	June 8	6–8 inches	258	147	57.0	1.2	21.3	27.9	6.6			
	June 21	12 inches	237	188	79.3	0	34.2	25.3	19.8	[6] 8	1	40
	July 17	Silk	195	195	100.0	2.1	48.7	32.3	16.9			
May 17	June 21	12 inches	216	159	73.6	0	39.8	30.1	3.7	15	1	940
	July 17	Silk	199	199	100.0	1.0	52.3	37.7	9.0			
June 1	July 19	Tassel	188	186	98.9	11.2	64.9	19.1	3.7	25	3	785
June 14	July 17	10 inches	261	212	81.2	19.2	45.6	13.8	2.7			
	Aug. 10	Silk	268	268	100.0	1.1	42.2	44.8	11.9	0		
July 1	do	10–12 inches	247	246	99.6	9.7	27.1	29.1	33.6			
July 17	Sept. 4	Mature	170	170	100.0	0	1.8	22.9	75.3	0		
	do	14 inches (mature)	244	244	100.0	1.6	18.4	37.3	42.6	0		
Total or average										48	6	765

[1] *a*=light infection (small local leaf lesions); *b*=moderate infection (long leaf lesions extending into midvein); *c*=heavy infection (abundant leaf lesions, stunted plants with premature tassels); *d*=plants dead or dying.
[2] Seed from G. M. Smith.
[3] Seed from Associated Seed Growers.
[4] In 1935 increase in numbers was due to tillers (more than 1 plant to a hill).
[5] Many plants were killed by the fall armyworm (*Laphygma frugiperda* S. and A.).
[6] Poor ears.

study of underlying causes of wilt epiphytotics has been evident for some time. Beginning with 1934 such records have been kept at the Arlington Experiment Farm, Arlington, Va. (near Washington, D. C.) and in several other localities for from 1- to 4-year periods.

ARLINGTON EXPERIMENT FARM, 1934–37

During the four seasons 1934–37, resistant and susceptible varieties of sweet corn were planted at the Arlington farm at intervals of approximately 15 days, beginning about May 1 and continuing through July 15. Golden Cross Bantam was used as the resistant variety, and Golden Bantam inbreds or open-pollinated commercial varieties from sections where the disease does not occur, were used as the susceptible variety. Records were kept of the number of infected plants and of the degree of infection, since the latter differs greatly in resistant and susceptible varieties. Two records of amount of wilt in each planting are given here, as they are representative of the amount of wilt developing in any one planting and variety. The first of these records shows the amount of wilt when the plants were about 10 inches high and the second when they were in tassel and silk. In 1936, because of the late development of the disease, additional records were taken when the ears were ready to harvest and also after harvest. These wilt records are given in table 1, which shows differences in amount of wilt in resistant and susceptible varieties, changes in amount of wilt in each in successive seasons, and differences in early- and late-season development of wilt.

Resistant and susceptible varieties of sweet corn differ in the numbers of lesions developing and in the extent and size of individual lesions. In a comparison of the amount of wilt in the two varieties, 100 percent of infected plants means much more serious damage in susceptible than in resistant varieties. In 1934 all plants of both varieties became infected, but in the resistant variety most of the plants showed only light to moderate infection and only 1 to 8 percent were dead. In the susceptible variety 18 to 20 percent were heavily infected and an additional 19 to 44 percent were dead or dying. Similar differences were apparent in all 4 years. The percentages of heavily infected and dead plants were very low in Golden Cross Bantam and comparatively high in Gill Bros. Improved Golden Bantam. Average percentages of infected plants in all plantings are shown in table 2. Golden Cross Bantam showed much less infection in the early leaf stage, and the lesions were more limited in development; as a result, there was much less reduction in yield.

Although resistant and susceptible varieties differ greatly in degree of infection and reduction in yield, they apparently respond alike to change in season, and striking differences are observed in the records for the four seasons. In 1934, 1935, and 1937 wilt was abundant early in the season, and as the season advanced, more than half of the plants of the susceptible variety became heavily infected or died and few marketable ears were harvested. In the resistant variety most plantings showed some early infection, and in 1934 and 1935 a few heavily infected or dead plants. In 1936 the situation was very different. The well-developed plots of susceptible sweet corn were in marked contrast to the heavily infected plots of the other three seasons. The striking thing about the wilt situation in 1936 was the small number

of infected plants early in the season and the abundant general infection that developed early in August and continued through the remainder of the season. In 1936 infections in both resistant and susceptible varieties were largely confined to the leaves. Since the general infection came too late to interfere with the development of the plants, the percentage of heavily infected or dead plants for the season was low and there was a good crop of marketable ears even on the early susceptible variety.

TABLE 2.—*Average percentages of infected plants in all plantings of two varieties of corn*

Variety and stage	Plants infected in—			
	1934	1935	1936	1937
Golden Cross Bantam:	*Percent*	*Percent*	*Percent*	*Percent*
Leaf stage	6.4	19.1	1.3	50.6
Tassel	100.0	54.9	41.4	97.8
Gill Bros. Improved Golden Bantam:				
Leaf stage	59.2	69.7	8.7	79.8
Tassel	100.0	86.5	44.2	99.8

The low wilt records (table 1) for 1936 at the Arlington Farm were even more apparent in other sweet corn plantings. In a series of plots of Top Cross Spanish Gold and Golden Early Market, planted May 22, the results were as shown in table 3.

TABLE 3.—*Wilt infection in plots of Top Cross Spanish Gold and Golden Early Market Sweet Corn at the Arlington Experiment Farm, Arlington, Va., 1936*

[Planted May 22]

Variety	Plot No.	Date of record	Condition	Rows	Plants					
					Total	Infected	Showing indicated degree of infection			
							Light	Moderate	Heavy	Dead
				No.	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Top Cross Spanish Gold	301	June 29	10 inches	5	89	0.0	0.0	0.0	0.0	0.0
		July 15	Tassel	5	81	.0	.0	.0	.0	.0
		Aug. 6	Silk	5	74	67.6	60.8	6.8	.0	.0
	306	June 29	10 inches	5	63	.0	.0	.0	.0	.0
		July 15	Tassel	5	61	.0	.0	.0	.0	.0
		Aug. 6	Silk	5	60	50.0	43.3	6.7	.0	.0
	312	June 29	10 inches	5	77	.0	.0	.0	.0	.0
		July 15	Tassel	5	74	.0	.0	.0	.0	.0
		Aug. 6	Silk	5	73	21.9	19.2	2.7	.0	.0
	315	June 29	10 inches	5	65	.0	.0	.0	.0	.0
		July 15	Tassel	5	62	.0	.0	.0	.0	.0
		Aug. 6	Silk	5	62	45.2	38.7	6.5	.0	.0
	5 rows 132 feet	June 29	12 inches	5	308	.0	.0	.0	.0	.0
		July 15	Tassel	5	305	3.6	3.0	.7	.0	.0
		Aug. 11	Silk	5	302	88.4	60.9	27.2	.3	.0
Golden Early Market	303	June 29	10 inches	5	78	.0	.0	.0	.0	.0
		July 15	Tassel	5	76	7.9	7.9	.0	.0	.0
		Aug. 6	Silk	5	66	48.5	31.8	13.6	1.5	1.5
	305	June 29	10 inches	5	81	.0	.0	.0	.0	.0
		July 15	Tassel	5	78	6.4	5.1	1.3	.0	.0
		Aug. 6	Silk	5	73	83.6	42.5	30.1	8.2	2.7
	310	June 29	10 inches	5	108	.0	.0	.0	.0	.0
		July 15	Tassel	5	108	2.8	1.9	.0	.0	.9
		Aug. 6	Silk	5	103	29.1	20.4	8.7	.0	.0
	316	June 29	10 inches	5	93	.0	.0	.0	.0	.0
		July 15	Tassel	5	92	2.2	2.2	.0	.0	.0
		Aug. 6	Silk	5	90	28.9	24.4	4.4	.0	.0
	5 rows 132 feet	June 29	10 inches	5	384	1.0	.3	.3	.3	.3
		July 15	Tassel	5	380	11.6	8.4	1.8	.8	.5
		Aug. 11	Silk	5	372	68.5	42.7	20.7	.0	5.1

There were four small plots of five rows each of Top Cross Spanish Gold and Golden Early Market adjacent to the plantings referred to in table 1. In addition, five 132-foot rows of each of these varieties were planted on another section of the Arlington farm, several hundred yards from the small plots and across a narrow roadway from plots of small grain. Top Cross Spanish Gold is more resistant than Golden Early Market. No evidence of wilt infection was found in the small plots of either variety until after the first of July. A few light infections were found in Golden Early Market the middle of July. By the first week in August both varieties showed from about 22 to 88 percent of infected plants. An interesting fact shown in table 3 is that in both varieties wilt developed earlier and was more severe in the five 132-foot rows than in the smaller plots.

Table 4 shows the percentages of infected plants in 10 open-pollinated varieties of sweet corn at the Arlington farm in 1936. Up to the first of July little or no infection appeared on these plants. About half of the plants of each variety were inoculated the first week in July. There were, therefore, two sets of infected plants—those in which the disease was due to natural infection and those in which it was due to inoculation. It is apparent from the data that there was little or no natural infection early in the season. It is also apparent that abundant infection developed in inoculated plants. The season was therefore favorable for each type of infection but the disease failed to develop naturally, evidently because inoculum was wanting. The data in table 4 show also that as the season advanced natural infection became much more abundant, in some cases as abundant as infection on inoculated plants. There were very few corn flea beetles (*Chaetocnema pulicaria* Melsh.) early in the season, but the number increased as the season advanced. The abundance of wilt and the abundance of adults of *C. pulicaria* were apparently closely correlated on the Arlington farm in 1936.

Wilt records at the Arlington farm showed a definite relation of wilt to winter temperatures. In figure 1 are given the mean and mean normal and the minimum and mean minimum temperatures for the winter months December, January, and February, for 1925–37, in Washington, D. C. The mean temperatures for the earlier years are given merely to show the succession of above-normal winters leading up to the unusually mild winters of 1931–32 and 1932–33. The winters of 1933–34 and 1934–35 were similar to each other. In 1933–34 the average winter temperature was slightly below normal but well above 32° F. Minimum temperatures for the 3 months were 8°, 8°, and −6°, respectively, making the average for February 24.6°, or 10° below normal. In 1934–35 the average was slightly above normal, with minimum temperatures of 17°, −2°, and 6°. In 1935–36 the winter was much colder, the average temperature being slightly below 32°. Although the minima of 4°, 0°, and 3° did not quite equal the lowest temperature in each of the preceding years, the average was lower. In 1936–37 the winter was much warmer than normal, the average being above 40° with minima for the 3 months of 14°, 29°, and 20°, respectively, and almost as high an average as for the winter of 1932–33.

TABLE 4.—*Percentages of infected plants in open-pollinated varieties of sweet corn at the Arlington Experiment Farm, Arlington, Va., 1936*

[Planted May 22]

Sweet corn varieties	Date of record	Condition	Plants						
			Total	Infected		Showing indicated degree of infection			
						a	*b*	*c*	*d*
			No.	*No.*	*Percent*	*No.*	*No.*	*No.*	*No.*
Golden Bantam	July 6	About 10 inches	42	1	2.380	0	1	0	0
	July 14	Tassel	[1] 23	16	69.565	7	9	0	0
			[2] 19	0	.00	0	0	0	0
	Aug. 5	Harvest	[1] 23	23	100.00	3	12	8	0
			[2] 19	12	63.157	10	1	1	0
Early Crosby	July 6	10 inches	23	0	.00	0	0	0	0
	July 14	Tassel	[1] 12	10	83.33				
			[2] 11	0	.00	0	0	0	0
	Aug. 5	Harvest	[1] 12	12	100.00	0	2	3	7
			[2] 11	9	81.81	8	1	0	0
Black Mexican	July 6	About 10 inches	25	0	.00	0	0	0	0
	July 14	Tassel	[1] 12	6	50.00	2			
			[2] 13	0	.00	0	0	0	0
	Aug. 5	Harvest	[1] 11	11	100.00	2	9	0	0
			[2] 13	9	69.231	9	0	0	0
Spanish Gold	July 6	About 10 inches	22	0	.00	0	0	0	0
	July 14	Tassel	[1] 11	4	36.36				
			[2] 11	0	.00	0	0	0	0
	Aug. 5	Mature	[1] 11	11	100.00	1	1	5	4
			[2] 11	10	90.90	7	3	0	0
White Cob Cory	July 6	8 inches	8	0	.00	0	0	0	0
	July 14	10 inches	[1] 3	3	100.00	3	0	0	0
			[2] 5	0	.00	0	0	0	0
	Aug. 5	Tassel to silk	[1] 3	3	100.00	0	0	3	0
			[2] 5	5	100.00	5	0	0	0
Golden Sunshine	July 6	10 inches	41	0	.00	0	0	0	0
	July 14	Tassel	[1] 21	15	71.428				
			[2] 20	0	.00	0	0	0	0
	Aug. 5	Harvest	[1] 21	21	100.00	2	2	9	8
			[2] 20	20	100.00				
Whipple's Yellow	July 6	10 inches	48	2	4.166	0	2	0	0
	July 14	Tassel	[1] 25	19	76.00	0	19	0	0
			[2] 23	1	4.347	0	1	0	0
	Aug. 5	Harvest	[1] 25	23	92.00	1	17	4	1
			[2] 23	11	47.826	10	1	0	0
Bantam Evergreen	July 6	10 inches	26	0	.00	0	0	0	0
	July 14	Tassel	[1] 12	10	83.33	0	10	0	0
			[2] 14	1	7.142	0	1	0	0
	Aug. 5	Silk	[1] 12	11	91.666	2	7	2	0
			[2] 14	10	71.429	10	0	0	0
Stowell Evergreen	July 6	About 10 inches	41	0	.00	0	0	0	0
	July 14	About 20 inches	[1] 17	11	64.705	11	0	0	0
			[2] 16	0	.00	0	0	0	0
	Aug. 5	Tassel and silk	[1] 17	12	70.588	2	10	0	0
			[2] 16	3	18.75	3	0	0	0
Country Gentleman	July 6	10 inches	31	0	.00	0	0	0	0
	July 14	16 inches	[1] 17	5	29.411	5	0	0	0
			[2] 14	0	.00	0	0	0	0
	Aug. 5	Silk	[1] 16	11	68.75	6	5	0	0
			[2] 13	2	15.385	2	0	0	0

[1] Plants inoculated July 6 to July 9 with *Aplanobacter stewarti*, 36–15–49.
[2] Not inoculated.

Unfortunately, there are no wilt records for the epiphytotic year of 1933 for comparison with succeeding years and therefore no way of demonstrating that average percentages of infection were lower in 1934, although, from field observations, this was undoubtedly the case. The average winter temperature for 1934–35 was slightly above that for the preceding year, the averages for December and February being slightly above and for January slightly below normal. In Golden Cross Bantam early infection in the first planting was less in 1935 than in 1934, but the records for the susceptible variety show more early infection. The average percentages for the 2 years indicate less wilt in 1935 than in 1934. But the very decided decrease in wilt

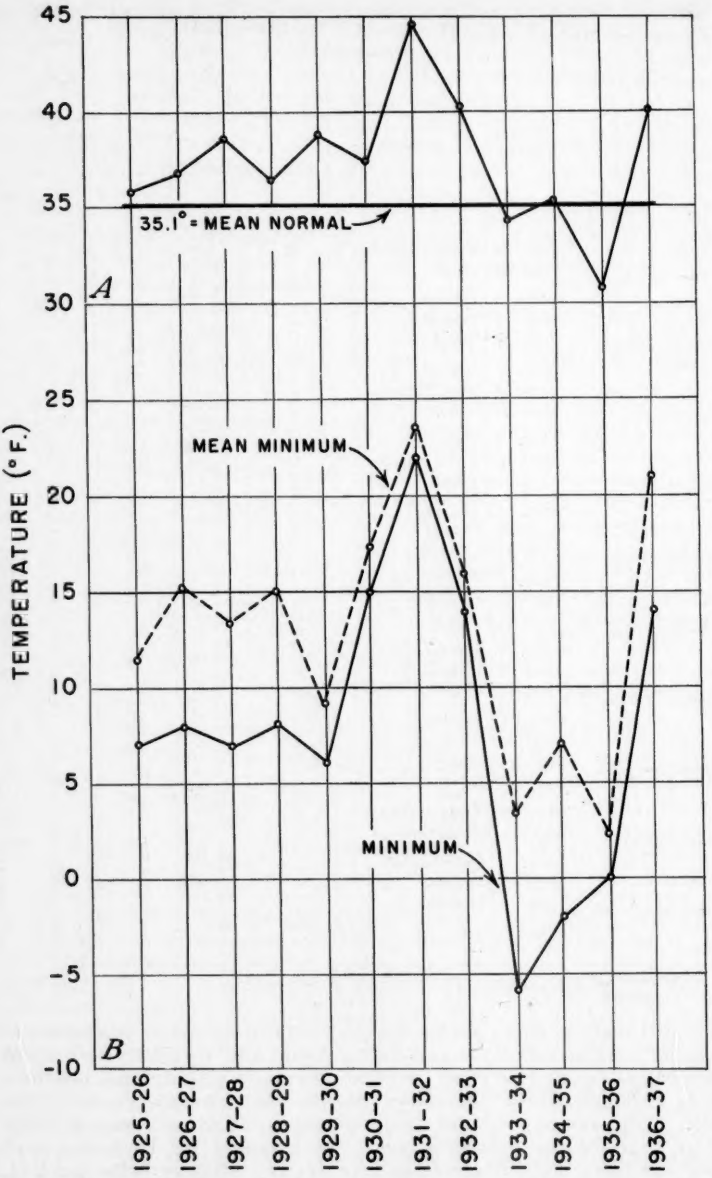

FIGURE 1.—Temperatures for December, January, and February, 1925–37, Washington, D. C.: *A*, Mean temperatures; *B*, minimum and mean minimum temperatures.

came in 1936, following the consistently low temperatures of the winter months; and wilt was abundant again early and throughout the season in 1937, following the warm winter of 1936–37. Wilt at the Arlington farm has followed closely these changes in winter temperature.

Because of the small size of the corn flea beetle, its extreme activeness, and other habits that are influenced directly by weather conditions and other factors, no practicable method of determining exact populations of this insect has been developed. However, field collections and observations on number of beetles and number of feeding injuries on corn leaves at the Arlington farm during 1934, 1935, and 1937 have shown that these beetles were much more abundant on young corn early in the season of these years than in 1936, when it was difficult at times to collect enough beetles for experimental purposes. At the same time there was little spread of the disease from the primary infections early in 1936. As the season advanced the adults of *Chaetocnema pulicaria* increased in number until August when they were fairly abundant on corn.

In 1937, corn flea beetles were again abundant early in the season. Factors not yet well understood are undoubtedly important in influencing winter survival of this insect. With few beetles to spread the primary infections in the spring and early summer, early infection appears to be reduced.

With a warm winter such as that of 1936–37 at Washington, D. C., following the late-season increase in number of beetles and general late-season infection on the corn plants in 1936, any retarding effect of one cold winter upon the early development of wilt the second season, which Haenseler[8] has called a "lag" period, would not be apparent. In colder sections, where beetles may be less abundant and infection of corn plants less general, the retarding effect of a single cold winter probably would be more apparent.

In the plantings of Top Cross Spanish Gold and Golden Early Market it was noted that, in both varieties, wilt developed earlier and was more severe in the five long rows than in the smaller plots. *Chaetocnema pulicaria* appeared to be more abundant on these long rows than on other corn plots on the Arlington farm and probably moved onto these corn rows early in July from the small-grain plots located across a narrow roadway.

OTHER LOCALITIES, 1935–37 [9]

Records have been made of the development of bacterial wilt in plantings at Ithaca, N. Y., in 1935, at Yonkers, N. Y., in 1935, 1936, and 1937, and at La Fayette, Ind., Toledo, Ohio, Geneva, N. Y., and Hempstead, Long Island, N. Y., in 1936 and 1937, and from these plantings field collections of possible insect vectors were made during the growing season. The wilt records from these stations are given in table 5.

[8] See footnote 5.

[9] The writers are indebted to the following persons for aid in this work: To G. M. Smith, of the Bureau of Plant Industry, for taking records on the disease at La Fayette, Ind., and at Toledo, Ohio; to E. V. Walter, of the Bureau of Entomology and Plant Quarantine, for collections of insects from Indiana; to Ralph Mathes, of the same Bureau, for the collections of insects from Toledo; to W. A. Baker, of the same Bureau for maintenance of the sweet-corn plots at Toledo; to B. L. Richards, of the Nassau County Farm Bureau, for assistance with the field plots and for making most of the collections of insects on Long Island; and to H. G. Walker and L. D. Anderson, of the Virginia Truck Experiment Station, for most of the insect collections obtained from Norfolk, Va.

TABLE 5.—*Percentages of infected plants in plantings of resistant and susceptible sweet corn varieties at various localities*

Variety	Date planted	Date of record	Condition on date of record	Rows	Plants						
					Total	Infected		Showing indicated degree of infection			
								Light	Moderate	Heavy	Dead
				No.	No.	No.	Pct.	Pct.	Pct.	Pct.	Pct.
GENEVA, N. Y.											
Golden Cross Bantam	*1936*										
	May 15	June 19	10 inches	2	47	0	0.0	----	----	----	----
		Aug. 14	Silk	2	41	0	.0	----	----	----	----
	June 1	...do	...do	2	40	0	.0	----	----	----	----
	June 15	...do	Tassel	1	66	0	.0	----	----	----	----
	1937										
	June 26	Aug. 28	Silk	1	85	6	7.1	3.5	3.5	0.0	0.0
	July 15	...do	18 inches	1	74	1	1.4	1.4	.0	.0	.0
	Aug. 2	...do	6 inches	1	121	0	.0	.0	.0	.0	.0
Gill Bros. Improved Golden Bantam	*1936*										
	May 15	June 19	12 inches	2	58	0	.0	----	----	----	----
		Aug. 14	Harvest	2	58	0	.0	----	----	----	----
	June 1	...do	Silk	2	44	0	.0	----	----	----	----
	June 15	...do	Tassel	1	70	0	.0	----	----	----	----
	1937										
	June 26	Aug. 28	Silk	1	77	8	10.4	10.4	.0	.0	.0
	July 15	...do	Tassel	1	110	12	10.9	6.4	4.5	.0	.0
	Aug. 2	...do	6 inches	1	130	0	.0	.0	.0	.0	.0
ITHACA, N. Y.											
Golden Cross Bantam	*1935*										
	May 26	June 29	10 inches	3	214	0	0.0	0.0	0.0	0.0	0.0
		Aug. 15	Silk	3	252	5	2.0	.8	1.2	.0	.0
	June 6	June 29	6 inches	3	250	0	.0	.0	.0	.0	.0
		Aug. 15	Silk	3	254	3	1.2	1.2	.0	.0	.0
	June 20	...do	Tassel	3	238	1	.4	.4	.0	.0	.0
	June 28	...do	3 feet	3	246	0	.0	.0	.0	.0	.0
Gill Bros. Improved Golden Bantam	May 26	June 29	8 inches	3	136	0	.0	.0	.0	.0	.0
		Aug. 15	Silk	3	198	6	3.0	2.0	1.0	.0	.0
	June 6	June 29	4 inches	3	----	0	.0	.0	.0	.0	.0
		Aug. 15	Silk	3	192	7	3.6	1.0	2.6	.0	.0
	June 20	...do	Tassel	3	112	2	1.8	.9	.9	.0	.0
	June 28	...do	...do	3	120	3	.5	2.0	2.5	.0	.0
Golden Bantam	(1)	June 29	...do	3	100	0	.0	.0	.0	.0	.0
YONKERS, N. Y.											
Golden Cross Bantam	*1935*										
	May 15	June 28	10 inches	3	131	0	0.0	0.0	0.0	0.0	0.0
		Aug. 19	Harvest	3	277	0	.0	.0	.0	.0	.0
	May 31	June 28	8 inches	3	233	1	.4	.0	.0	.0	.4
		Aug. 19	Silk	3	290	0	.0	.0	.0	.0	.0
	June 15	June 28	4 inches	3	----	0	.0	.0	.0	.0	.0
		Aug. 19	Silk	3	172	2	1.2	1.2	.0	.0	.0
	July 1	...do	Tassel	3	314	0	.0	.0	.0	.0	.0
Gill Bros. Improved Golden Bantam	May 15	June 28	10 inches	3	136	2	1.5	.0	.7	.7	.0
		Aug. 19	Tassel	3	191	17	8.9	1.6	4.2	.0	3.1
	May 31	June 28	6 inches	3	257	3	1.2	1.2	.0	.0	.0
		Aug. 19	Roasting ear	3	257	11	4.3	1.2	.4	.0	2.7
	June 15	June 28	----	----	----	----	----	----	----	----	----
		Aug. 19	Silk	3	141	1	.7	.0	.0	.0	.7
	July 1	...do	Tassel	3	240	2	.8	.4	.0	.4	.0
Golden Bantam	(1)	June 28	20 inches	6	616	11	1.8	.3	.3	.5	.6
		Aug. 19	14 inches	3	333	30	9.0	.0	.9	3.3	4.8
	1936										
	(1)	June 17	10 inches	6	700	0	.0	.0	.0	.0	.0
		Aug. 13	Silk	6	700	26	3.7	3.4	.0	.3	.0
	1937										
	May 18	June 25	12 inches	1	246	12	4.9	.4	2.4	1.2	.8
	June 2	Aug. 27	Harvest	1	113	112	99.1	.0	67.3	16.8	15.0
	June 17	...do	Silk	1	166	165	99.4	5.4	80.1	9.0	4.8

[1] Planted in home garden but date not known.

TABLE 5.—*Percentages of infected plants in plantings of resistant and susceptible sweet corn varieties at various localities*—Continued

HEMPSTEAD, LONG ISLAND, N. Y.

Variety	Date planted	Date of record	Condition on date of record	Rows	Plants					
					Total	Infected		Showing indicated degree of infection		
								Light	Moderate	Heavy	Dead
	1936			*No.*	*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
	May 17	June 17	10 inches	1	71	0	0.0	0.0	0.0	0.0	0.0
		July 9	Tassel	1	71	2	2.8	.0	.0	2.8	.0
		Aug. 13	Silk	1	68	68	100.0	79.4	16.2	4.4	.0
	June 1	July 9	Tassel	1	71	0	.0	.0	.0	.0	.0
		Aug. 13	Harvest	1	73	72	98.6	86.3	6.8	5.5	.0
Golden Cross Bantam	June 16	do	Tassel	1	75	67	89.3	68.0	16.0	5.3	.0
	1937										
	May 15	June 25	10 inches	1	97	7	7.2	.0	1.0	6.2	.0
	June 1	do	6 inches	1	101	0	.0	.0	.0	.0	.0
	June 15	do	3 inches	1	91	0	.0	.0	.0	.0	.0
		Aug. 27	Mature	1	91	91	100.0	72.5	27.5	.0	.0
	1936										
	May 13	June 17	12 inches	1	82	2	2.4	.0	1.2	1.2	.0
		July 9	Tassel	1	79	13	16.5	2.5	2.5	8.9	2.5
		Aug. 13	Mature	1	79	69	87.3	26.6	36.7	3.8	20.3
Gill Bros. Improved Golden Bantam	June 1	July 9	Tassel	1	80	10	12.5	1.3	5.0	5.0	1.3
		Aug. 13	Harvest	1	74	74	100.0	39.2	36.5	17.6	6.8
	June 16	do	Silk	1	73	71	97.3	63.0	19.2	11.0	4.1
	1937										
	May 15	June 25	8 inches	1	104	9	8.7	.0	.0	3.8	4.8
	June 1	do	5 inches	1	92	1	1.1	.0	1.1	.0	.0
	July 1	Aug. 27	Mature	1	83	83	100.0	6.0	32.5	53.0	8.4

TOLEDO, OHIO [2]

	1936										
	May 15	Aug. 1		1	225	3	1.3				
	June 1	do		1	246	1	.4				
	June 15	do		1	316	0	.0				
	1937										
	May 15	June 25		1	187	0	.0	0.0	0.0	0.0	0.0
		July 20		1	187	0	.0	.0	.0	.0	.0
		Aug. 13		1	187	0	.0	.0	.0	.0	.0
Golden Cross Bantam	June 1	June 25		1	220	0	.0	.0	.0	.0	.0
		July 20		1	220	0	.0	.0	.0	.0	.0
		Aug. 13		1	220	0	.0	.0	.0	.0	.0
	June 15	July 20		1	215	0	.0	.0	.0	.0	.0
		Aug. 13		1	215	2	.9	.9	.0	.0	.0
		Sept. 4		1	215	31	14.4	11.6	.0	1.9	.9
	July 1	July 20		1	183	0	.0	.0	.0	.0	.0
		Aug. 13		1	183	4	2.2	.5	.0	.5	1.1
		Sept. 4		1	183	13	7.1	4.4	.0	2.7	.0
	1936										
	May 15	Aug. 1		1	266	1	.4				
	June 1	do		1	299	2	.7				
	June 15	do		1	311	0	.0				
	1937										
	May 15	June 25		1	148	0	.0	.0	.0	.0	.0
		July 20		1	148	1	.7	.0	.0	.0	.7
		Aug. 13		1	148	12	8.1	.7	.0	2.0	5.4
Gill Bros. Improved Golden Bantam	June 1	June 25		1	168	0	.0	.0	.0	.0	.0
		July 20		1	168	0	.0	.0	.0	.0	.0
		Aug. 13		1	168	2	1.2	.0	.0	.6	.6
	June 15	July 20		1	177	0	.0	.0	.0	.0	.0
		Aug. 13		1	177	5	2.8	2.8	.0	.0	.0
		Sept. 4		1	177	177	100.0	65.5	.0	16.9	17.5
	July 1	July 20		1	193	0	.0	.0	.0	.0	.0
		Aug. 13		1	193	19	9.8	.5	.0	2.1	7.3
		Sept. 4		1	193	159	82.4	38.9	.0	30.1	13.5

[2] Notes taken by Glenn M. Smith.

TABLE 5.—*Percentages of infected plants in plantings of resistant and susceptible sweet corn varieties at various localities*—Continued

LA FAYETTE, IND.[2]

Variety	Date planted	Date of record	Condition on date of record	Rows	Plants						
					Total	Infected		Showing indicated degree of infection			
								Light	Moderate	Heavy	Dead
	1936			*No.*	*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
	May 15	July 31		1	201	0	0.0	----	----	----	----
	June 1	do		1	215	0	.0	----	----	----	----
	June 15	do		1	190	0	.0	----	----	----	----
	1937										
	May 15	June 26		1	217	0	.0	0.0	0.0	0.0	0.0
		July 21		1	217	0	.0	.0	.0	.0	.0
		Aug. 14		1	217	0	0	.0	.0	.0	.0
Golden Cross Bantam	June 1	June 26		1	267	0	.0	.0	.0	.0	.0
		July 21		1	267	0	.0	.0	.0	.0	.0
		Aug. 14		1	267	0	.0	.0	.0	.0	.0
	June 15	July 21		1	241	0	.0	.0	.0	.0	.0
		Aug. 14		1	241	0	.0	.0	.0	.0	.0
		Sept. 5		1	241	7	2.9	1.7	.0	1.2	.0
	June 30	July 21		1	203	0	.0	.0	.0	.0	.0
		Aug. 14		1	203	5	2.5	1.5	.0	.5	.5
		Sept. 5		1	203	10	4.9	2.5	.0	2.0	.5
	1936										
	May 15	July 31		----	195	0	.0	----	----	----	----
	June 1	do		----	190	0	.0	----	----	----	----
	June 15	do		----	210	0	.0	----	----	----	----
	1937										
	May 15	June 26		1	179	0	.0	.0	.0	.0	.0
		July 21		1	179	0	.0	.0	.0	.0	.0
		Aug. 14		1	179	0	.0	.0	.0	.0	.0
Gill Bros. Improved Golden Bantam	June 1	June 26		1	223	0	.0	.0	.0	.0	.0
		July 21		1	223	0	.0	.0	.0	.0	.0
		Aug. 14		1	223	0	.0	.0	.0	.0	.0
	June 15	July 21		1	211	0	.0	.0	.0	.0	.0
		Aug. 14		1	211	0	.0	.0	.0	.0	.0
		Sept. 5		1	211	117	55.5	35.5	.0	11.4	8.5
	June 30	July 21		1	171	0	.0	.0	.0	.0	.0
		Aug. 14		1	171	10	5.8	.6	.0	.6	4.7
		Sept. 5		1	171	163	95.3	48.5	.0	35.1	11.7

[2] Notes taken by Glenn M. Smith.

At Geneva, N. Y., the northernmost station, not a single wilt lesion was found in 1936 in either variety up to August 14, when the plants were tasseling and the last record was taken. Also, no wilt lesions were found in the station variety plots. In 1937, 7 percent of the plants of the resistant variety were infected and almost 11 percent of the susceptible variety.

At Ithaca, a little farther south, records are available only for 1935, when leaf lesions occurred on 2 percent or less of the resistant variety and on not more than 4 percent of the plants of the susceptible variety.

At Yonkers, which is in the southeastern part of New York, still farther south than Ithaca, field plots of Golden Cross and Gill Bros. Improved Golden Bantam were planted at Boyce Thompson Institute only in 1935. In 1936 and 1937 wilt records from the same garden were made from plantings of commercial Golden Bantam. In 1935 only 1 percent of wilted plants occurred in the resistant Golden Cross and 9 percent in the susceptible Gill Bros. Improved Golden Bantam. But infection apparently took place early enough to kill a large part

of the infected plants. In 1936 no wilt was found on June 17 on 700 Golden Bantam plants. On August 13, when the plants were in silk, 26, or 4 percent, were infected. Two of these plants showed heavy infection, and 24 light or recent infection. In 1937 wilt was much more abundant. Five percent of the plants were infected early in their growth, and 99 percent when mature or in silk, 17 percent being heavily infected and 15 percent dead.

Wilt conditions on Long Island in 1936 were similar to those at the Arlington farm in seasonal development and amount of wilt. There was little wilt early in the season but abundant wilt by the middle of August and relatively few plants heavily infected or dead. Wilt records for 1937 are incomplete, but they show more early infection than in 1936.

At Toledo, Ohio, only late records are available for 1936, and these show less than 2 percent of infected plants. In 1937 no wilt was found on Golden Cross Bantam before the middle of August and only traces in Gill Bros. Improved Golden Bantam, but by the first of September, wilt had become general on the latter variety.

Although no wilt was found on the plots at La Fayette, Ind., in 1936, 0.2 and 0.25 percent of infected plants in two inbred lines, June 29, and 0.066 percent of infected plants in a field of 30,000 plants of susceptible varieties, were reported for the same locality in 1936.[10] In the same publication another observer reported 1 to 2 percent of infected plants, June 10, in open-pollinated Golden Bantam, about 25 miles south of La Fayette, and 10 percent, about 90 miles south, on June 13. These figures are cited to show that wilt was present in small amounts in the vicinity of La Fayette in 1936, although it did not appear in the small experimental plantings. No wilt was observed in La Fayette early in 1937, but by September over 50 and 90 percent of two plantings were infected and nearly half of the plants were heavily infected or dead.

Mean winter temperatures and minimum temperatures for 1925–37 are given in figure 2 for the above mentioned stations or for the nearest weather stations.

Mean temperatures for Geneva, N. Y., show most winter temperatures well below 32° F. with minimum temperatures usually well below 0° and as low as −31°. At Geneva no wilt or only traces occurred in most years. In 1936, when mean winter temperatures were below 32° and when no wilt was found, no specimens of *Chaetocnema pulicaria* were collected in three attempts, weather conditions at this time not being the most favorable for collecting this species. However, evidence of feeding by adult *C. pulicaria* was observed at Geneva, August 25, showing that there were a few beetles in that locality late in the season. In 1937, when mean winter temperatures were well above 32° and when as many as 10 percent of the plants were infected with wilt, 57 specimens of *C. pulicaria* were collected August 18, and 10 of these, or 17.5 percent, were found to be infested with *Aplanobacter stewarti*.

At Toledo, Ohio, mean winter temperatures were somewhat higher than at Geneva, but still were well below 32° F., with minimum temperatures usually well below 0°, in most years. At Toledo, in 1936, only an occasional specimen of *Chaetocnema pulicaria* was collected up

[10] UNITED STATES BUREAU OF PLANT INDUSTRY. BACTERIAL WILT OF CORN IN 1936. U. S. Bur. Plant Indus., Plant. Dis. Rptr. 20: 252. 1936. [Mimeographed.]

to the last of July. From that time on, several hundred beetles were collected and sent in for isolation tests, but not an infested beetle was

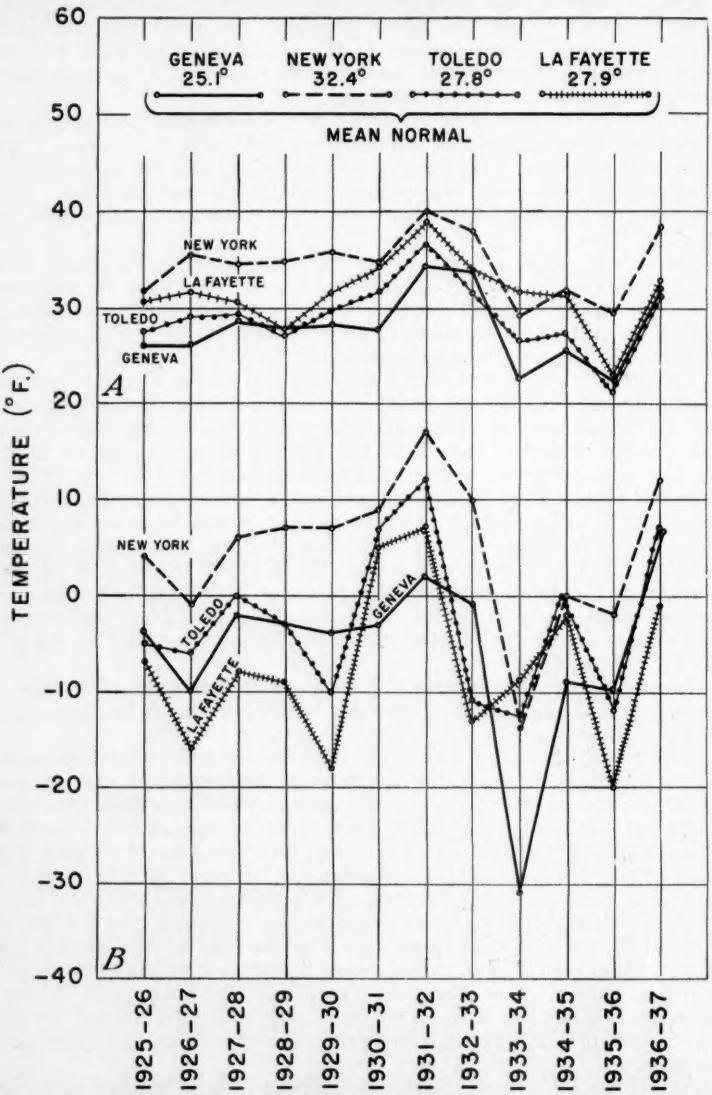

FIGURE 2.—Temperatures for December, January, and February, 1925–37, at Geneva, N. Y., New York, N. Y., Toledo, Ohio, and La Fayette, Ind.: *A*, Mean temperatures; *B*, minimum temperatures.

found. It will be recalled that less than 2 percent of infected plants were recorded for Toledo in 1936. In 1936–37 at Toledo, mean winter

temperatures were well above normal and just a little below 32°, and the minimum for all three winter months was 7°. Larger numbers of *C. pulicaria* were collected in June and July as well as later in the season. Only about 1 percent were infested in June and July, but 50 percent were infested the middle of August.

At La Fayette, mean winter temperatures were near 32° F., but minimum temperatures were often well below 0°. In 1935–36 temperatures went much lower, with an average below 24° and a minimum of −20°. No wilt was found in the field plots in July of 1936. A few beetles were collected the middle of the season (74 on June 23) but none was infested. Fairly large numbers were collected as the season advanced, and the percentage infested also increased. In 1936–37 winter temperatures were well above normal and a little above 32°, with a minimum of −1°. No wilt was recorded during June and July of 1937, but in September it became general on susceptible sweet corn. Fairly large numbers of *Chaetocnema pulicaria* were collected throughout the season. Percentages infested were low early in the season and increased as the season advanced.

On Long Island and in Yonkers, N. Y., where mean winter temperatures and minimum temperatures are higher than at Geneva, wilt is more abundant.

It is apparent from these data that the numbers of wilt-infected plants are closely associated with winter temperatures. In sections where mean winter temperatures are well below 32° F., fewer corn flea beetles apparently survive than where mean winter temperatures are well above 32°. It is also evident at the Arlington farm that the beetles may increase greatly in number during a growing season and so probably become a source of infection for the following year if enough of them survive until the corn crop develops. Factors not clearly understood may in some seasons prevent midsummer increase in the severity of wilt, even in the presence of an abundance of beetles.

INSECT VECTORS OF APLANOBACTER STEWARTI

The work on insect vectors was continued along lines previously reported for 1934 (*9*), and methods already described were followed. For the most part, insects that feed on corn under field conditions were collected from various localities, disinfected externally, and crushed in broth from which dilution plates were poured to determine which species and what proportion of the individuals of each species were carrying *Aplanobacter stewarti* internally. Most of the isolations from *Chaetocnema pulicaria* were made from individual insects. Isolations from other species were made from broth suspensions of from 1 to as many as 123 specimens. During 1934, isolations for *A. stewarti* were made from 7,331 insects representing 37 species belonging to 32 genera; in 1935, from 9,390 insects representing 57 species belonging to 48 genera; in 1936, from 5,696 insects representing 60 species belonging to 49 genera; and in 1937, from 6,352 insects representing 29 species belonging to 24 genera, making for the 4 years a total of 28,769 insects from 94 species belonging to 76 genera. Twenty-seven additional species not previously used were tested for the wilt organism in 1935, 23 in 1936, and 7 in 1937. In many instances, the number of isolations from a single species was small because few individuals belonging to the species were collected from corn. In 1937 isolations were made from a few species that were

collected only from hibernating quarters near infected cornfields of the previous year, because of the possibility of their harboring the organism over winter. The results of the isolations made during the period 1934–37 are summarized in table 6, in which 94 species belonging to 76 genera, involving a total of 28,769 specimens, are tabulated. *A. stewarti* was obtained from 27 percent of the *C. pulicaria* in 1934, from 22 percent in 1935, from 20 percent in 1936, and from 30 percent in 1937; and from 7 percent of the *C. denticulata* in 1934, from 4 percent in 1935, from 2 percent in 1936, and from 4 percent in 1937.

TABLE 6.—*Summary of insects*[1] *collected in the field in 1934–37 and tested for Aplanobacter stewarti*

Order and scientific name[2]	Common name	Year	Total specimens	Localities	Species of hosts	Isolations made	Isolations tested by inoculation on corn	Isolations of *A. stewarti*	
			No.	*No.*	*Approximate No.*	*No.*	*No.*	*No.*	*Pct.*
Coleoptera:		1934	173	9	6	32	7	2	6.3
Chaetocnema confinis Crotch.[3]	Sweetpotato flea beetle (a. n. o.)[4]	1935	706	30	11	111	13	2	1.8
		1936	387	11	6	73	9	0	.0
		1937	23	4	2	22	0	0	.0
		1934	905	16	9	366	89	26	7.1
Chaetocnema denticulata (Ill.).[3]	Toothed flea beetle	1935	597	28	9	112	17	4	3.6
		1936	95	11	8	82	7	2	2.4
		1937	409	15	8	289	35	12	4.2
		1934	4,790	29	12	3,360	1,330	916	27.3
Chaetocnema pulicaria Melsh.[3]	Corn flea beetle (a. n. o.).	1935	5,588	45	10	5,404	1,420	1,198	21.8
		1936	3,809	20	5	3,809	881	743	19.5
		1937	4,426	26	8	4,426	1,470	1,315	29.7
		1934	178	3	5	20	7	0	.0
Diabrotica duodecimpunctata (Fab.).[3]	Spotted cucumber beetle (a. n. o.).	1935	322	24	10	54	6	3	5.6
		1936	127	4	5	33	4	0	.0
		1937	11	2	2	7	1	0	.0
Disonycha glabrata (Fab.).	Flea beetle	1934	2	1	1	1	1	1	100.0
		1934	365	13	6	49	5	0	.0
Epitrix cucumeris (Harr.).[3]	Potato flea beetle (a. n. o.).	1935	332	18	8	27	5	1	3.7
		1936	255	10	8	37	8	2	5.4
		1937	198	6	3	8	0	0	.0
Phalacrus sp.	Smut beetle (a. n. o.).	1936	90	8	6	22	2	0	.0
		1937	31	6	4	12	1	1	8.3
		1934	7	1	1	2	1	1	50.0
Stilbus apicalis (Melsh.).[3]	Shining flower beetle	1935	138	8	7	16	4	1	6.3
		1936	1	1	1	1	0	0	.0
		1937	2	1	1	1	1	0	.0
		1934	22	1	1	3	1	0	.0
Stilbus viduus Casey.[3]	do	1935	142	16	7	24	4	1	4.2
		1936	23	4	5	6	4	0	.0
		1937	38	6	5	12	0	0	.0
Hemiptera:									
Nabis ferus (L.)[3]	Nabid bug	1934	1	1	1	1	1	0	.0
		1935	1	1	1	1	0	0	.0
		1936	22	2	3	7	2	1	14.3
		1937	4	2	2	2	1	0	.0
Homoptera:									
Illinoia solanifolii (Ashm.).[3]	Potato aphid (a. n. o.).	1934	155	2	1	55	5	1	1.8
		1935	260	2	1	4	0	0	.0
Stirellus bicolor (Van D.).[3]	Leafhopper	1934	4	1	1	1	1	1	100.0
		1935	3	1	1	2	0	0	.0
Thamnotettix nigrifrons (Forbes).[3]	Black-faced leafhopper.	1934	132	1	1	5	2	1	20.0
		1935	88	2	1	7	2	0	.0
		1936	1	1	1	1	0	0	.0
Thysanoptera:		1934	66	2	1	9	1	0	.0
Anaphothrips obscurus (Müll.).	Grass thrips	1935	70	3	1	4	0	0	.0
		1936	467	1	1	10	3	1	10.0

INSECTS FROM WHICH A. STEWARTI WAS ISOLATED

[1] Listed alphabetically according to orders; under each order, alphabetically by genera.

[2] The assistance of various taxonomic specialists in the Bureau of Entomology and Plant Quarantine is gratefully acknowledged.

[3] Also tested for *Aplanobacter stewarti* after feeding for several days on infected corn in cages, but data not included in this summary.

TABLE 6.—*Summary of insects* [1] *collected in the field in 1934–37 and tested for Aplanobacter stewarti*—Continued

INSECTS FROM WHICH A. STEWARTI WAS NOT ISOLATED

Order and scientific name	Common name	Years tested	Insects tested
Coleoptera:			*Number*
Aeolus amabilis Lec.		1937	108
Brachytarsus sticticus Boh.		1935	5
Ceratomegilla fuscilabrus (Muls.)[2]	Spotted ladybird	1935–37	29
Cerotoma trifurcata (Forst.)	Bean leaf beetle	1935	1
Chaetocnema minuta Melsh.	Flea beetle	1935	11
Chauliognathus pennsylvanicus (DeG.)	Soldier bug	1935, 1937	10
Collops quadrimaculatus (Fab.)	Four-spotted beetle	1934–37	13
Crepidodera atriventris Melsh.	Acalypha flea beetle	1936	17
Diabrotica longicornis (Say)	Corn rootworm (a. n. o.) [4]	1935–36	3
Diabrotica vittata (Fab.)	Striped cucumber beetle (a. n. o.)	1935, 1937	7
Dibolia borealis Chev.	Leaf beetle	1934, 1935	51
Dibolia sp.	do	1936	2
Disonycha xanthomelaena (Dalm.)[2]	Spinach flea beetle	1934–37	14
Epicauta pennsylvanica (DeG.)	Black blister beetle (a. n. o.)	1936	4
Epilachna varivestis Mul.	Mexican bean beetle (a. n. o.)	1934–37	12
Epitrix parvula (Fab.)[2]	Tobacco flea beetle (a. n. o.)	1934–36	61
Epitrix sp.	Flea beetle	1936	3
Euphoria inda (L.)	Bumble flower beetle (a. n. o.)	1936	1
Glischrochilus fasciatus (Oliv.)		1936	2
Hippodamia convergens Guer.[2]	Convergent ladybeetle (a. n. o.)	1935, 1937	7
Hippodamia parenthesis (Say)	Ladybeetle	1936	1
Hypera nigrirostris (Fab.)	Lesser clover leaf weevil (a. n. o.)	1935	7
Hypera punctata (Fab.)	Clover leaf weevil (a. n. o.)	1934, 1936	4
Lacon rectangularis (Say)		1937	8
Languria mozardi Latr.	Clover stem borer	1937	11
Leptinotarsa decemlineata (Say)	Colorado potato beetle (a. n. o.)	1936	6
Lixus concavus Say	Rhubarb curculio (a. n. o.)	1936	1
Macrodactylus subspinosus Fab.	Rose chafer (a. n. o.)	1935	13
Mantura floridana Crotch		1935, 1937	8
Melanophthalma distinguenda Com.		1935–37	48
Meligethes aeneus LeC.		1935	31
Nodonota puncticollis (Say)	Rose leaf beetle (a. n. o.)	1935	4
Notoxus calcaratus Horn		1937	1
Phalacrus politus Melsh.	Smut beetle (a. n. o.)	1934–36	34
Phyllotreta vittata (Fab.)	Striped flea beetle (a. n. o.)	1934–36	23
Popillia japonica Newm.	Japanese beetle (a. n. o.)	1937	31
Psylliodes sp.	Flea beetle	1935–36	33
Scymnus sp.	Ladybeetle	1936	11
Sitona cylindricollis (Fab.)	Curculio	1936	4
Sitona hispidula (Fab.)	Clover root curculio (a. n. o.)	1936	1
Stilbus sp.	Shining flower beetle	1936–37	27
Systena blanda (Melsh.)	Pale-striped flea beetle (a. n. o.)	1934–36	8
Systena hudsonias (Forst.)	Flea beetle	1935	1
Systena taeniata Auct.	do	1935–36	24
Tetraopes tetraophthalmus Forst.	Red milkweed beetle (a. n. o.)	1935–36	2
Triachus atomus (Suffr.)		1936	2
Collembola:			
Sminthurus sp.	Springtail	1934	8
Hemiptera:			
Adelphocoris rapidus (Say)[2]	Rapid plant bug (a. n. o.)	1934–36	4
Allocoris pulicaria (Germ.)		1936–37	3
Anasa armigera (Say)		1937	1
Blissus leucopterus (Say)	Chinch bug (a. n. o.)	1936–37	989
Euschistus variolarius (P. de B.)	Stinkbug	1936	8
Geocoris punctipes (Say)[2]	Plant bug	1934–35	8
Halticus citri (Ashm.)[2]	Garden flea hopper (a. n. o.)	1936	21
Lygus pratensis oblineatus (Say)[2]	Tarnished plant bug (a. n. o.)	1934–37	191
Orius insidiosus (Say)[2]	Insidious flower bug	1934–36	517
Trigonotylus ruficornis (Geoffr.)		1935–36	29
Homoptera:			
Aceratagallia sanguinolenta (Prov.)	Clover leafhopper	1934–36	7
Agallia constricta Van D.[2]	Leafhopper	1934–36	73
Aphis maidis Fitch [2]	Corn leaf aphid (a. n. o.)	1936	19
Balclutha sp.	Leafhopper	1935	5
Chlorotettix viridius Van D.	do	1935	1
Delphacodes sp.		1935	1
Deltocephalus flavicostus Stal.	Leafhopper	1934	1
Draeculacephala mollipes (Say)[2]	Tenderfoot leafhopper	1934–36	15
Empoasca sp.[2]	Leafhopper	1934–36	290
Erythanus obscurinervis (Stal)	do	1936	1
Macrosiphum sp.	Aphid	1936	20
Macrosteles divisus (Uhl.)	Six-spotted leafhopper (a. n. o.)	1934–36	185
Micrutalis calva (Say)	Treehopper	1934	1
Norvellina seminuda (Say)	Leafhopper	1934, 1936	4
Philaenus leucophthalmus (L.)	Spittle bug	1935	105

[1] Listed alphabetically according to orders; under each order, alphabetically by genera.

[2] Also tested for *Aplanobacter stewarti* after feeding for several days on infected corn in cages, but data not included in this summary.

[4] a. n. o. = American name, official; i. e., common name adopted by the American Association of Economic Entomologists.

TABLE 6.—*Summary of insects* [1] *collected in the field in 1934–37 and tested for Aplanobacter stewarti*—Continued

INSECTS FROM WHICH A. STEWARTI WAS NOT ISOLATED—Continued

Order and scientific name	Common name	Years tested	Insects tested
Homoptera—Continued.			*Number*
Phlepsius irroratus (Say)	Irrorate leafhopper	1935–36	2
Polyamia inimica (Say)	Inimical leafhopper	1934–36	5
Scaphytopius cinereus (O. and B.)	Leafhopper	1936	1
Scaphytopius frontalis (Van D.)	do	1935–36	2
Stobaera tricarinata (Say)	Fulgorid	1935	5
Lepidoptera:			
Heliothis armigera (Hbn.) (larvae)	Corn earworm (a. n. o.)	1937	20
Orthoptera:			
Conocephalus fasciatus (DeG.)	Grasshopper (nymph)	1935	1
Thysanoptera:			
Aeolothrips fasciatus (L.)	Thrips	1936	5
Aeolothrips fasciatus (L.)		1934	50
Anaphothrips obscurus (Müll.)			

[1] Listed alphabetically according to orders: under each order, alphabetically by genera.

CHAETOCNEMA PULICARIA [11]

ABUNDANCE AND DISTRIBUTION OF INFESTED ADULTS

The corn flea beetle (*Chaetocnema pulicaria*), as previously reported, appears to be the most important insect vector of the wilt organism among the species tested. From the data obtained to date, it also appears to be the only species of importance that harbors the organism over winter and carries it to the young corn in the spring.

Chaetocnema pulicaria usually occurs in much greater abundance on corn throughout most of the season than any of the other insects from which *Aplanobacter stewarti* has been isolated (*9*). During 1934, 4,790 specimens from 29 localities and 12 host plants were used in isolation tests; in 1935, 5,588 specimens from 45 localities and 10 hosts; in 1936, 3,809 specimens from 20 localities and 5 hosts; and in 1937, 4,426 specimens from 26 localities and 8 hosts; making a total of 18,613 specimens of *C. pulicaria* tested in the 4 years. Table 7 gives in detail the percentages of *C. pulicaria* infested with *A. stewarti* under field conditions at the Arlington farm during the 4-year period 1934–37. *C. pulicaria* was much less abundant in the field in 1936 than in the other 3 years. In the spring and early summer, the percentage of heavily infested beetles was slightly lower than in midsummer and fall, indicating that as the number of infected corn plants increased, the proportion of beetles carrying an abundance of the organisms also increased. The seasonal life history of this insect is not yet well enough known to correlate the fluctuation in the proportion of adults infested with the appearance of new broods.

The data from collections of *Chaetocnema pulicaria* at the Arlington farm for the period 1934–37 are summarized in table 8.

The data presented in table 8 show that the proportion of infested *Chaetocnema pulicaria* obtained from sweet corn was consistently higher than that obtained from other hosts. The larger percentage of infested *C. pulicaria* found on sweet corn at the Arlington farm in 1936 than in 1934 and 1935 was probably due to the fact that in 1936 collections from this host were made late in the season only, when wilt was more abundant in the field. The percentage of *C. pulicaria* infested with *Aplanobacter stewarti* collected from sweet corn in 1937 was low, probably because 100 of the 225 adults tested were collected

[11] Coleoptera, Chrysomelidae.

May 25 from sweet corn transplanted from the greenhouse to a spot located several hundred yards from infected corn of the previous season. Only 2 percent of these 100 beetles yielded *A. stewarti*. If this collection is omitted from the calculations, the remaining 125 adult *C. pulicaria*, all collected on infected sweet corn after July 18, will yield an average of 46.4 percent infested with *A. stewarti*. The percentages, by months, of *C. pulicaria* found to be carrying the wilt organism internally at the Arlington farm during the 4-year period are likewise shown in table 8.

TABLE 7.—*Percentage of Chaetocnema pulicaria infested with Aplanobacter stewarti under field conditions at the Arlington Experiment Farm, Arlington, Va.*

Date collected	Host	Adults tested by isolation	Proportion yielding *A. stewarti*		Date collected	Host	Adults tested by isolation	Proportion yielding *A. stewarti*	
1934		*No.*	*No.*	*Pct.*	*1935*		*No.*	*No.*	*Pct.*
May 1	Grass	18	2	11.1	July 8	Corn (sweet)	99	49	49.4
14	Corn (sweet)	85	0	0	15	do	100	59	59.0
16	Grass	4	1	25.0	22	do	100	49	49.0
16	Wheat	57	10	17.5	Sept. 25	Alfalfa	100	31	31.0
16	Corn (sweet)	54	10	18.5	27	Grass	100	32	32.0
18	do	83	11	13.2	Oct. 28	Sudan grass	110	8	7.2
June 18	Panic grass	100	0	0	Nov. 5	Alfalfa	110	35	31.8
20	Corn (field)	50	22	44.0	5	Grass	100	21	21.0
20	do	50	20	40.0		Total or average	1,765	493	27.9
July 9	Corn (sweet)	100	75	75.0	*1936*				
31	do	100	38	38.0	Mar. 25	Grass	104	25	24.0
Aug. 1	Sudan grass	100	19	19.0	Apr. 15	do	100	13	13.0
8	do	66	8	12.1	May 13	do	70	8	11.4
10	Corn (sweet)	90	45	50.0	June 2	Corn (field)	94	20	21.2
10	Panic grass	10	2	20.0	July 2	Panic grass	53	0	0
15	Alfalfa	100	9	9.0	2	Corn (field)	54	1	1.8
19	Corn (sweet)	100	36	36.0	14	do	100	2	2.0
28	do	100	47	47.0	27	do	48	7	14.5
Sept. 5	do	100	58	58.0	Aug. 19	Corn (sweet)	100	51	51.0
11	Sudan grass	100	6	6.0	Sept. 8	do	95	51	53.6
19	Corn (sweet)	46	26	56.5	23	do	60	43	71.6
19	Sudan grass	47	1	2.1	Oct. 19	Grass	100	31	31.0
Oct. 2	do	52	8	15.3	Nov. 2	do	100	38	38.0
22	Alfalfa and grass	100	3	3.0		Total or average	1,078	290	26.9
Nov. 5	Grass	105	7	6.6	*1937*				
22	do	60	9	15.0	Jan. 8	Grass	100	30	30.0
	Total or average	1,877	473	25.2	Mar. 25	do	23	4	17.3
1935					Apr. 6	do	100	26	26.0
Mar. 22	Grass	100	7	7.0	May 25	Corn (sweet)	100	2	2.0
25	do	100	6	6.0	June 23	Corn (field)	100	2	2.0
30	do	100	2	2.0	July 19	Corn (sweet)	50	19	38.0
Apr. 25	do	97	9	9.2	19	Grass	50	6	12.0
May 14	do	38	6	15.7	Aug. 11	Corn (sweet)	60	29	48.3
28	Corn (sweet)	100	28	28.0	11	Grass	40	4	10.0
June 3	do	63♀	32	50.7	Sept. 15	Corn (sweet)	15	10	66.6
3	do	31♂	16	51.6	15	Grass	87	23	26.4
3	do	5	3	60.0	Oct. 12	do	50	12	24.0
10	do	100	45	45.0	12	Alfalfa (grassy)	50	6	12.0
15	do	84♀	1	1.2	Nov. 8	Weeds, grass, etc	85	19	22.3
15	do	31♂	0	0		Total or average	910	192	21.0
26	do	94	54	57.4					
27	do	1	0	0					

♀ Female. ♂ Male.

Although these data are incomplete they indicate that higher percentages of these beetles were carrying the wilt organism during July, August, and September than during other months of the year. It seems clear that while the percentages of infested *Chaetocnema pulicaria* at the Arlington farm early in the season were higher in 1936 than in 1935, midseason percentages were lower, and late-season percentages again were higher.

TABLE 8.—*Proportion of adults of Chaetocnema pulicaria, infested with Aplanobacter stewarti, collected from sweet corn and other hosts at the Arlington Experiment Farm, Arlington, Va., 1934–37*

Host and year	Period of collection	Total adults	Adults infested										
			Average	Jan.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
		No.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Sweet corn:													
1934	May 14 to Sept. 19	908	40.3	----	----	----	9.4	40.0	56.5	44.1	57.5	----	----
1935	May 28 to July 22	808	41.5	----	----	----	28.0	36.9	52.5	----	----	----	----
1936	Aug. 19 to Sept. 23	255	56.8	----	----	----	----	----	----	51.0	60.6	----	----
1937	May 25 to Sept. 15	225	[1] 26.6	----	----	----	2.0	----	38.0	48.3	66.6	----	----
Other hosts:													
1934	May 1 to Sept. 19	669	12.1	----	----	----	16.4	14.6	5.8	13.8	4.7	7.2	9.6
1935	Mar. 22 to Nov. 5	955	16.4	----	5.0	9.2	15.7	----	----	----	31.5	7.2	26.6
1936	Mar. 25 to Nov. 2	823	17.6	----	24.0	13.0	11.4	21.2	3.9	----	----	31.0	38.0
1937	Jan. 8 to Nov. 8	685	19.2	30.0	17.3	26.0	----	2.0	12.0	10.0	26.4	18.0	22.3

[1] See text p. 664 for explanation of low figure.

Table 9 gives detailed information on the percentage of *Chaetocnema pulicaria* infested with *Aplanobacter stewarti* under field conditions when collected from localities other than the Arlington farm during the 4-year period 1934–37. Excluding collections of 10 adults of *C. pulicaria* or less, high percentages (30 percent or more) of infested beetles collected from localities other than the Arlington farm for the 4-year period are shown in table 10.

TABLE 9.—*Percentage of Chaetocnema pulicaria, from localities other than the Arlington Experiment Farm, Arlington, Va., infested with Aplanobacter stewarti*

1934

Date collected	Host	State	Adults tested	Proportion yielding *A. stewarti*	
			Number	*Number*	*Percent*
May 5	Oats	South Carolina	112	0	0.0
May 7	Corn	do	145	0	.0
May 8	Weeds	North Carolina	19	0	.0
May 11	Oats	Virginia	59	0	.0
June 6	do	Maryland	67	11	16.4
Do	Corn	do	50	3	6.0
Do	do	New Jersey	8	0	.0
Do	Tomato	do	72	0	.0
June 10	Oats	do	3	0	.0
June 22	Corn	Virginia	50	14	28.0
Do	do	do	50	8	16.0
June 27	do	Pennsylvania	16	4	25.0
Do	do	do	5	3	60.0
July 2	do	Virginia	50	8	16.0
July 11	do	do	54	30	55.5
Do	do	do	50	3	6.0
July 17	do	New Jersey	85	18	21.1
Do	do	Delaware	97	19	19.5
July 18	do	Connecticut	4	0	.0
July 20	do	New York	5	0	.0
July 21	do	Pennsylvania	68	28	41.1
Do	do	do	100	15	15.0
Do	do	do	100	2	2.0
Aug. 21	do	Virginia	100	40	40.0
Do	do	North Carolina	27	5	18.6
Aug. 30	do	Virginia	100	29	29.0
Sept. 6	do	do	100	16	16.0
Sept. 10	do	Ohio	2	0	.0
Oct. 8	Corn and grass	Missouri	110	18	16.3
Oct. 10	Corn	Kansas	160	7	4.3
Oct. 15	Rye and alfalfa	Illinois	97	38	39.1
Total or average			1,965	319	16.2

TABLE 9.—*Percentage of Chaetocnema pulicaria, from localities other than the Arlington Experiment Farm, Arlington, Va., infested with Aplanobacter stewarti*—Continued

1935

Date collected	Host	State	Adults tested	Proportion yielding *A. stewarti*	
			Number	*Number*	*Percent*
April 2	Grass	Virginia	110	11	10.0
Do	do	do	3♂	0	.0
Do	do	do	1♀	0	.0
Do	do	do	98	5	5.1
Do	do	do	1♂	0	.0
Do	do	do	2♀	0	.0
April 19	Bluegrass	Missouri	6	1	16.6
April 20	do	Ohio	83	2	2.4
Do	Grass	Indiana	111	7	6.3
Do	do	Ohio	8	0	.0
April 28	do	Virginia	117	7	5.9
May 7	do	North Carolina	100	2	2.0
Do	Oats	Virginia	30	1	3.3
May 8	do	North Carolina	55	2	3.6
Do	Grass	do	16	2	12.5
Do	Corn	South Carolina	2	0	.0
Do	Alfalfa	do	1	0	.0
Do	Corn	do	49	0	.0
May 9	do	do	52	1	1.9
Do	do	do	84	9	10.7
May 10	do	Virginia	67	12	17.9
May 11	Grass	do	19	1	5.2
Do	Alfalfa	do	7	0	.0
May 15	Oats	Maryland	100	22	22.0
Do	Grass	do	3	2	66.6
Do	Wheat	Delaware	25	3	12.0
May 16	Corn	New Jersey	100	36	36.0
Do	Oats	do	99	13	13.1
May 17	Grass	Connecticut	2	0	.0
May 21	Corn	Maryland	55	0	.0
May 22	Grass	Pennsylvania	100	31	31.0
Do	Oats	do	9	3	33.3
May 31	Corn	Virginia	100	13	13.0
June 6	do	do	6	2	33.3
June 7	do	North Carolina	7	1	14.2
Do	do	do	14	1	7.1
June 11	do	Virginia	140	28	20.0
June 18	Oats	Pennsylvania	120	24	20.0
June 24	Corn	do	23	1	4.3
Do	do	New Jersey	1	0	.0
July 1	do	Virginia	100	34	34.0
July 12	do	do	100	38	38.0
July 16	do	New Jersey	100	43	43.0
July 17	do	New York	100	52	52.0
Do	do	do	28	12	42.8
July 18	do	Connecticut	47	6	12.7
July 19	do	New York	13	1	7.6
July 20	do	Pennsylvania	60	8	13.3
Do	do	do	60	6	10.0
Do	do	do	47	14	29.7
Aug. 14	do	do	24	6	25.0
Aug. 16	do	New York	28	3	10.7
Aug. 17	do	Connecticut	45	10	22.2
Aug. 18	do	New York	55	31	56.3
Sept. 24	Alfalfa	Virginia	100	37	37.0
Oct. 8	Corn	do	98	29	29.5
Oct. 12	Alfalfa	West Virginia	100	27	27.0
Oct. 13	do	Illinois	64	6	9.3
Do	Clover	do	40	13	32.5
Oct. 14	Grass	Missouri	100	5	5.0
Oct. 15	Alfalfa	Kansas	100	3	3.0
Oct. 19	Grass	Indiana	100	10	10.0
Do	do	Ohio	110	20	18.1
Nov. 5	do	Virginia	100	29	29.0
Total or average			3,645	686	18.8

1936

Feb. 26	Rye	Virginia	80	4	5.0
Mar. 24	do	do	110	3	2.7
Apr. 13	do	do	112	7	6.2
Apr. 20	Bluegrass	Ohio	68	4	5.8
Apr. 28	Grass	Virginia	39	3	7.6
Apr. 29	Rye	do	93	4	4.3

TABLE 9.—*Percentage of Chaetocnema pulicaria, from localities other than the Arlington Experiment Farm, Arlington, Va., infested with Aplanobacter stewarti*—Continued

1936—Continued

Date collected	Host	State	Adults tested	Proportion yielding *A. stewarti*	
			Number	*Number*	*Percent*
Apr. 29	Grass	North Carolina	100	6	6.0
May 6	Corn	South Carolina	93	3	3.2
Do	Rye	Virginia	88	22	25.0
May 15	Corn	Indiana	3	0	.0
Do	Grass	do	5	0	.0
May 25	Corn	Pennsylvania	21	1	4.7
Do	do	do	2	2	100.0
Do	do	Ohio	4	1	25.0
May 26	do	Virginia	100	10	10.0
Do	do	Indiana	11	0	.0
May 27	do	New York	46	3	6.5
June 4	do	Ohio	1	0	.0
June 9	do	Virginia	100	41	41.0
June 15	do	Ohio	1	0	.0
June 23	do	Indiana	74	0	.0
June 25	do	Ohio	1	0	.0
July 6	do	do	1	0	.0
July 16	do	do	6	0	.0
July 21	?	New York	19	3	15.7
Do	Corn	Indiana	61	1	1.63
July 22	do	Virginia	86	40	46.5
July 23	do	do	50	23	46.0
Do	do	do	50	20	40.0
July 28	do	Ohio	30	0	.0
July 29	Corn and yellow bristle grass.	Pennsylvania	48	0	.0
July 31	Corn	do	50	0	.0
Aug. 7	do	Ohio	70	0	.0
Aug. 12	do	New York	40	19	47.5
Do	do	Virginia	50	16	32.0
Aug. 17	do	Ohio	113	0	.0
Aug. 25	do	Pennsylvania	92	4	4.3
Aug. 26	do	New York	5	0	.0
Aug. 27	do	do	100	49	49.0
Do	do	Ohio	100	0	.0
Aug. 28	do	Delaware	100	39	39.0
Sept. 1	do	Indiana	4	0	.0
Do	do	do	100	60	60.0
Sept. 8	do	Ohio	100	0	.0
Oct. 6	Rye	New York	75	33	44.0
Oct. 20	Grass	Indiana	53	14	26.4
Nov. 2	?	Virginia	100	18	18.0
Nov. 7	Bluegrass	Ohio	76	0	.0
Dec. 28	do	Indiana	8	1	12.5
Dec. 30	Grass	do	3	1	33.3
Total or average			2,742	455	16.5

1937

Jan. 10		Virginia	100	13	13.0
Apr. 21	Grasses	do	50	9	18.0
Do	do	do	50	11	22.0
May 3	Grass	Ohio	100	7	7.0
May 7	do	Indiana	38	2	5.2
May 8	do	do	21	2	9.5
May 12	do	Ohio	4	0	.0
May 13	Field corn	North Carolina	100	10	10.0
May 29	Sweet corn	New Jersey	63	32	50.7
Do	Field corn	Delaware	100	8	8.0
Do	Sweet corn	New Jersey	100	27	27.0
Do	Field corn	Maryland	88	0	.0
June 1	Sweet corn	New York	54	22	40.7
June 3	do	Pennsylvania	30	1	3.3
June 4	Field corn	do	45	0	.0
Do	do	do	50	2	4.0
June 9	Sweet corn	New Jersey	100	71	71.0
June 15	Field and sweet corn	Ohio	100	1	1.0
June 17	Sweet corn	New Jersey	100	64	64.0
June 21	Dent corn	Indiana	69	30	43.4
June 24	Sweet corn	New Jersey	100	63	63.0
June 26	Field corn	Pennsylvania	100	4	4.0
June 29	Sweet corn	New York	48	26	54.1
July 8	Field corn	New Jersey	100	48	48.0

TABLE 9.—*Percentage of Chaetocnema pulicaria, from localities other than the Arlington Experiment Farm, Arlington, Va., infested with Aplanobacter stewarti*—Continued

1937—Continued

Date collected	Host	State	Adults tested	Proportion yielding *A. stewarti*	
			Number	*Number*	*Percent*
July 19	Sweet corn	Indiana	25	1	4.0
Do	Dent corn	do	32	5	15.6
July 21	do	do	84	25	29.7
July 22	Field corn	New Jersey	86	64	74.3
July 23	Sweet and field corn	Ohio	93	1	1.0
July 26	Sweet corn	New York	100	75	75.0
Aug. 10	do	Indiana	26	12	46.1
Do	Dent corn	do	97	10	10.3
Aug. 11	Sweet corn	do	10	2	20.0
Aug. 13	do	Ohio	100	49	49.0
Aug. 17	Field corn	Pennsylvania	100	18	18.0
Do	do	do	48	6	12.5
Do	Grassy corn	do	21	7	33.3
Aug. 18	Sweet corn	New York	57	10	17.5
Do	do	do	17	6	35.2
Aug. 19	Corn	do	10	3	33.3
Do	Sweet corn	do	9	4	44.4
Do	do	do	45	21	46.6
Aug. 20	Field corn	New Jersey	100	54	54.0
Aug. 28	Sweet corn	New York	6	1	16.6
Sept. 2	do	do	93	70	75.2
Sept. 18	Bluegrass	Ohio	100	37	37.0
Sept. 20	Sweet corn	do	100	32	32.0
Sept. 23	Grass	New Jersey	88	43	48.8
Oct. 1	Sweet corn	Indiana	21	11	52.3
Do	Dent corn	do	77	15	19.4
Oct. 2	Sweet corn	do	50	14	28.0
Oct. 5	Rye	New York	100	50	50.0
Oct. 11	Sweet corn	Ohio	100	21	21.0
Total or average			3,505	1,120	31.9

TABLE 10.—*Percentage (30 percent or more) of infested Chaetocnema pulicaria collected in localities other than the Arlington Experiment Farm, Arlington, Va., 1934–37*

Date	Locality	Infested beetles	Date	Locality	Infested beetles
1934		*Percent*	*1936*		*Percent*
July 11	Charlottesville, Va	55.0	Aug. 27	Hempstead, N. Y	49.0
Aug. 21	Franklin, Va	40.0	Oct. 6	do	44.4
July 21	Hamburg, Pa	41.1	Sept. 1	La Fayette, Ind	60.0
Oct. 15	Madison County, Ill	39.1	*1937*		
1935			May 29	Burlington, N. J	50.7
July 1	Falls Church, Va	34.0	June 9	do	71.0
July 12	Norfolk, Va	38.0	June 17	do	64.0
Sept. 24	Falls Church, Va	37.0	June 24	do	63.0
May 22	Gettysburg, Pa	31.0	July 8	do	48.0
May 16	Burlington, N. J	36.0	July 22	do	74.4
July 16	do	43.0	Aug. 20	do	54.0
July 17	Hicksville, N. Y	52.0	Sept. 23	do	48.8
	Huntington Station, N. Y	42.8	June 1	Hempstead, N. Y	40.7
Aug. 18	Yonkers, N. Y	56.3	June 29	do	54.1
Oct. 13	Hamel, Ill	32.5	July 26	do	75.0
1936			Aug. 18	Watkins Glen, N. Y	35.2
			Aug. 19	Schenectady, N. Y	46.6
			Sept. 2	Hempstead, N. Y	75.2
			Oct. 5	do	50.0
June 9	Falls Church, Va	41.0	Aug. 17	Williamsport, Pa	33.3
July 22	Holland, Va	46.5	Aug. 13	Toledo, Ohio	49.0
July 23	Norfolk, Va	46.0	Sept. 18	Marietta, Ohio	37.0
	Surry, Va	40.0	Sept. 20	Toledo, Ohio	32.0
Aug. 12	Holland, Va	32.0	June 21	La Fayette, Ind	43.4
Aug. 28	Glasgow, Del	39.0	Aug. 10	do	46.1
Aug. 12	Mineola, N. Y	47.5	Oct. 1	do	52.3

It would appear from these data that higher percentages of *Chaetocnema pulicaria* were carrying *Aplanobacter stewarti* in 1937, es-

pecially during August and September, than during the same months of the 3 preceding years. However, the collections during the 4-year period upon which these data are based were made at different times and from different localities and are therefore not entirely comparable.

Heavy seedings and practically pure cultures of the wilt organism were obtained in 83 percent of the 1,198 isolations of *Aplanobacter stewarti* from *Chaetocnema pulicaria* in 1935, in 76 percent of the 743 isolations made in 1936, and in 87 percent of the 1,315 isolations made in 1937. Less than 20 percent of the plates had from 1 to several colonies of *A. stewarti* in a mixture of other organisms.

Overwintering of Aplanobacter stewarti

As previously reported (*4*, *9*) about 19 percent of 175 adults of *Chaetocnema pulicaria* collected at the Arlington farm before corn came up in the spring of 1934 were found to be heavily infested with *Aplanobacter stewarti* when tested individually for this organism. Sweet corn plants in cages in the greenhouse developed typical symptoms of the wilt disease after adults of *C. pulicaria* from similar lots had fed on the leaves. Additional feeding tests of a similar nature were made during either March or April of the 3 years following, and similar results were obtained in each instance. Isolations of *A. stewarti* during 1935–37 from overwintered adults of *C. pulicaria* early in the season before corn had come up in the field and from adult beetles going into hibernation in October and November continued to furnish evidence of the overwintering of *A. stewarti* in this insect. The results of these early- and late-season isolations are given in table 11. The figures shown are not entirely comparable since the collections upon which they are based were not made at the same time and from the same localities and hosts from year to year. They indicate, however, that larger percentages of *C. pulicaria* about to hibernate were carrying the wilt organism in the fall of 1936 and 1937 than during the late fall of the two preceding years. Table 11 also indicates that high percentages of infested beetles coming out of hibernation in the spring apparently follow high percentages going into hibernation in the fall. In years when few infested beetles go into hibernation in the fall, ring tests have shown similar low percentages.

Table 11.—*Proportion of adults of Chaetocnema pulicaria harboring Aplanobacter stewarti in the spring and fall 1934–37*

Year	Spring			Fall		
	Localities	Adults tested	Proportion yielding wilt organism	Localities	Adults tested	Proportion yielding wilt organism
	Number	*Number*	*Percent*	*Number*	*Number*	*Percent*
VARIOUS LOCALITIES						
1934	1	175	19.3	4	684	13.1
1935	16	1,427	9.0	10	1,132	18.2
1936	6	964	10.2	5	504	26.5
1937	8	586	17.7	5	533	27.7
ARLINGTON EXPERIMENT FARM						
1934	1	175	19.3	1	317	8.5
1935	1	397	6.0	1	320	20.0
1936	1	204	18.6	1	200	34.5
1937	1	223	26.9	1	185	20.0

An attempt was made, insofar as possible, to make the collections from which these data were obtained in the same areas each season. However, this was not always possible and frequently there was much variation in the percentage of *Chaetocnema pulicaria* yielding the wilt organism from areas near infected corn of the previous season and from areas at distances of one-half mile or more from the corn. The foregoing data appear to indicate a considerable increase in the percentage of beetles carrying the wilt organism in the fall of 1935 and in the spring of 1936 and a still greater increase in the fall of 1936 and in the spring of 1937. The late development of wilt at the Arlington farm during 1936 probably was responsible for the higher percentages of infested beetles in the fall than in midsummer in 1936, and these higher percentages going into hibernation were in turn probably responsible for the higher percentages coming out of hibernation the following spring.

Aplanobacter stewarti was isolated from specimens of *Chaetocnema pulicaria* collected at the Arlington farm every month of the year except February during the 4-year period. Collections of *C. pulicaria* were made during the winter, whenever weather conditions were favorable for the beetles to become active. One lot of 80 individuals of this species, collected February 26, 1936, at Norfolk, Va., was used for isolation of *A. stewarti*, and 5 percent of these adults yielded the organism. As table 9 shows, *A. stewarti* was isolated from overwintering adults of *C. pulicaria* from every section of the country in which wilt had been at all prevalent.

Proportion of Each Sex Carrying the Wilt Organism and Maximum Infestation of Adults

In 1935 the sex of the adults was determined in 2 experiments in which field-collected specimens of *Chaetocnema pulicaria* were tested by isolation in the usual manner. In 1 test 16 isolations of *Aplanobacter stewarti* were obtained from 31 males and 32 isolations from 63 females, 51.6 percent as compared with 50.7 percent. These adults were collected at the Arlington farm, June 3, from sweet corn transplanted from the greenhouse in April and May. This test indicated no significant difference between the sexes in the proportion of adults carrying the wilt organism. A second test with adults collected from the same plants on June 15 yielded 1 culture of *A. stewarti* from 84 individual females and none from 31 males. An additional test was made July 3, 1935, in which a total of 103 individuals of *C. pulicaria* that had been confined to infected corn in cages for 5 days were tested in the usual manner for *A. stewarti*, and 86, or 83.4 percent, yielded the organism. The sex of 87 of these 103 beetles was determined as they were crushed in the broth, and 36 out of 46 females, or 78.2 percent, and 39 out of 41 males, or 95.1 percent, yielded the wilt organism. This was the highest percentage of *C. pulicaria* ever recorded as carrying *A. stewarti* internally. During 1934 (*9*) only 30.7 to 68 percent, or a weighted average of 55.6 percent, of the adults of *C. pulicaria* yielded *A. stewarti* in similar tests. The reason for the difference in the number of isolations of *A. stewarti* obtained in the first 2 tests is not clear, but the difference may have been due to the appearance of a new brood of *C. pulicaria* that had not become infested with the organism prior to being used for isolation.

The maximum infestation from field collections of adults of *Chaetocnema pulicaria* in 1934 was 75 percent on July 9 (table 7); in 1935, 59 percent on July 15 (excluding the collection of five adults made June 3); in 1936, 71.6 percent on September 23 (excluding the two adults collected May 25); and in 1937, 75.2 percent on September 2 (table 9). The highest percentages of beetles carrying the wilt organism were from adults collected on or near infected corn.

CHAETOCNEMA DENTICULATA [12]

Among the numerous species of insects tested for the bacterial wilt organism during the 4-year period 1934–37, *Chaetocnema denticulata* appears to be second in importance as a vector of *Aplanobacter stewarti* under field conditions. In 1934, 366 isolations from 905 specimens of *C. denticulata* yielded *A. stewarti* in 26 instances (table 6); in 1935, 112 isolations from 597 specimens yielded 4 cultures of *A. stewarti;* in 1936, 82 isolations from 95 specimens yielded only 2 cultures; and in 1937, 289 isolations from 409 specimens yielded 12 cultures. Table 12 summarizes the results of isolations from adults of *C. denticulata* collected at the Arlington farm to determine the wilt-carrying possibilities of this species, and table 13 gives similar data for collections from localities other than the Arlington farm.

At the Arlington farm during 1934–37, a total of 439 isolations were made from 927 adults of *Chaetocnema denticulata,* and *Aplanobacter stewarti* was obtained from 23 of these isolations. Of particular interest in connection with these studies was the fact that 17 of the 23 cultures were secured during August and September of 1934, when wilt apparently was most prevalent in the field. No cultures of *A. stewarti* were obtained in 1936, although 56 isolations from 59 adults were made. One culture was obtained from 25 isolations from a single adult *C. denticulata* collected January 8, 1937.

From localities other than the Arlington farm, during the 4-year period, 410 isolations were made from 1,079 adults of *Chaetocnema denticulata,* and 21 cultures of *Aplanobacter stewarti* were obtained as follows: 9 out of 192 in 1934, from adults collected from corn in Virginia during August and September; 1 out of 75 in 1935, from an adult collected from corn in Virginia; 2 out of 26 in 1936, one from corn and the other from rye, at Mineola, Long Island, N. Y.; and 9 out of 117 in 1937, from adults collected from sweet corn and grass (4 from sweet corn and grass in New Jersey, 4 from sweet corn at Mineola, and 1 from grass at Marietta, Ohio). While *C. denticulata* does carry the wilt organism, it is apparently not a very close second in inportance to *C. pulicaria* in the dissemination of wilt in the field. Moreover, it is very doubtful whether the organism ever overwinters in adults of *C. denticulata.* No isolations of the wilt organism have been obtained in March and April, although 3 isolations were made from *C. denticulata* collected from rye and grass in the fall and winter: One, November 5, 1935; another, October 6, 1936; and another, January 8, 1937. Several early and midseason isolations of what appeared to be *A. stewarti* on plates poured from broth suspensions of adult *C. denticulata* were not infectious.

[12] Coleoptera, Chrysomelidae.

TABLE 12.—*Number of Chaetocnema denticulata infested with Aplanobacter stewarti at the Arlington Experiment Farm, Arlington, Va.*

Date collected	Host	Insects per isolation	Isolations	Type of culture [1]	Proportion of isolations yielding *A. stewarti*	
		Number	*Number*		*Number*	*Percent*
1934						
Apr. 4	Alfalfa	2	1	C	0	0.0
Apr. 30	Rye	6	1	B	0	.0
May 16	Corn	1	1	C	0	.0
May 18	Alfalfa	8	1	C	0	.0
June 25	Corn	1	5	C	0	.0
July 31	do	1	2	2A	0	.0
Aug. 3	do	107	1	B	0	.0
Aug. 10	do	9	1	C	0	.0
Do	Grass	44	1	A	0	.0
Do	do	42	1	A	1	100.0
Aug. 15	Alfalfa	15	1	B	0	.0
Do	do	54	1	B	1	100.0
Aug. 17	Grass	1	115	7A, 8B	5, 1	5.2
Do	do	18	1	C	0	.0
Aug. 19	Corn	1	10	1B	0	.0
Do	do	5	4	3C, 1B	0, 1	.0, 25.0
Do	do	10	2	2B	2	100.0
Aug. 28	Grass	1	4	1B	1	25.0
Sept. 5	Corn	1	1	B	1	100.0
Do	do	1	1	A	1	100.0
Sept. 11	Sudan grass	1	9	2A, 1B	1, 0	11.1, .0
Do	do	2	1	C	0	.0
Do	do	3	1	C	0	.0
Do	do	5	1	C	0	.0
Do	do	5	2	2A	2	100.0
Sept. 19	Corn	5	1	A	0	.0
Do	Sudan grass	7	1	A	0	.0
Do	do	6	1	C	0	.0
Oct. 2	do	14	1	C	0	.0
		15	1	B	0	.0
Total or average		[2] 560	174		17	9.7
1935						
Mar. 21	Rye	1	4	C	0	0.0
Mar. 23	Grass	1	2	C	0	.0
Apr. 24	do	1	1	C	0	.0
May 14	do	6	1	B	0	.0
June 3	Corn	1	1	C	0	.0
June 26	do	1	3	2A	2	66.6
June 27	do	1	4	C	0	.0
June 28	do	1	5	C	0	.0
July 5	do	12	1	C	0	.0
Do	do	14	1	C	0	.0
July 6	do	66	1	C	0	.0
July 8	do	2	1	C	0	.0
July 23	do	1	1	A	0	.0
Do	do	1	1	C	0	.0
Sept. 26	Grass	1	9	1A	0	.0
Nov. 5	do	1	1	A	1	100.0
Total or average		132	37		3	8.1
1936						
Mar. 25	Grass	1	6	C	0	0.0
Apr. 15	do	1	42	1B	0	.0
July 2	Panic grass	1	5	C	0	.0
July 27	do	1	2	C	0	.0
Nov. 3	Grass	4	1	C	0	.0
Total or average		59	56		0	.0

See footnotes at end of table.

TABLE 12.—*Number of Chaetocnema denticulata infested with Aplanobacter stewarti at the Arlington Experiment Farm, Arlington, Va.*—Continued

1937

Date collected	Host	Insects per isolation	Isolations	Type of culture [1]	Proportion of isolations yielding *A. stewarti*	
		Number	*Number*		*Number*	*Percent*
Jan. 8	Grass	1	25	A	1	4.0
July 19	do	1	50	C		
Aug. 11	Sweet corn	1	25	A	1	4.0
Do	Grasses	1	25	C		
Sept. 15	Sweet corn	1	1	A	1	100.0
Do	Grass	1	1	C		
Oct. 12	do	1	2	C		
Do	Grassy alfalfa	1	7	C		
Do	do	5	1	C		
Nov. 8	Weeds, etc	1	35	C		
Total or average		176	172		3	1.7
Grand total		927	439		23	

[1] A=Typical colonies of *Aplanobacter stewarti;* B=atypical yellow colonies; C=no colonies.
[2] Total number of insects=insects per isolation × isolations.

TABLE 13.—*Number of Chaetocnema denticulata, from localities other than Arlington, Va., infested with Aplanobacter stewarti*

1934

Date collected	Host	State	Insects per isolation	Isolations	Type of culture [1]	Proportion of isolations yielding *A. stewarti*	
			Number	*Number*		*Number*	*Percent*
May 5	Oats	Georgia	18	1	A	0	0.0
May 11	Woods	Virginia	1	1	B	0	.0
June 6	Corn	New Jersey	1	1	C	0	.0
Do	Oats	Maryland	1	4	2B	0	.0
July 11	Corn	Virginia	1	41	2B	0	.0
Do	do	do	1	50	4A 7B	0	.0
July 18	do	Connecticut	10	1	B	0	.0
July 19	do	New York	19	1	B	0	.0
July 20	do	do	1	41	11B	0	.0
July 21	do	Pennsylvania	2	1	C	0	.0
Aug. 21	do	North Carolina	106	1	C	0	.0
Do	do	Virginia	1	16	3A 3B	1 2	18.7
Do	do	do	2	1	A	0	.0
Aug. 30	do	do	1	14	6A	5	35.7
Do	do	do	3	1	C	0	.0
Sept. 6	do	do	1	7	2A	1	14.2
Oct. 15	Rye	Illinois	1	10	1B	0	.0
Total or average			[2] 345	192		9	4.7

1935

Apr. 2	Grass	Virginia	1	1	A	0	0.0
Apr. 19	do	Missouri	1	27	C	0	.0
Apr. 20	do	Indiana	1	1	C	0	.0
May 7	do	North Carolina	1	1	C	0	.0
May 8	Oats	do	3	1	C	0	.0
Do	Grass	do	50	1	A	0	.0
Do	Corn	South Carolina	28	1	B	0	.0
Do	do	do	3	1	C	0	.0
May 9	do	do	3	1	C	0	.0
Do	Potato	do	2	1	C	0	.0
May 10	Corn	North Carolina	50	1	A	0	.0
May 11	Grass	Virginia	4	1	C	0	.0
May 15	Oats	Maryland	2	1	C	0	.0
May 16	Corn	New Jersey	10	1	A	0	.0
May 18	Grass	Connecticut	1	1	C	0	.0
May 19	Corn	do	2	1	C	0	.0
May 31	do	Virginia	1	1	B	1	100.0
June 6	do	do	1	1	C	0	.0
June 7	do	North Carolina	10	5	C	0	.0
Do	do	do	7	1	C	0	.0
Do	do	do	10	3	B	0	.0
Do	do	do	6	1	B	0	.0

See footnotes at end of table.

TABLE 13.—*Number of Chaetocnema denticulata, from localities other than Arlington, Va., infested with Aplanobacter stewarti*—Continued

1935—Continued

Date collected	Host	State	Insects per isolation	Isolations	Type of culture [1]	Proportion of isolations yielding *A. stewarti*	
			Number	*Number*		*Number*	*Percent*
June 11	Corn	Virginia	1	1	C	0	.0
June 23	do	Connecticut	1	1	C	0	.0
July 16	do	New Jersey	3	1	C	0	.0
July 17	do	New York	1	1	C	0	.0
July 18	do	Connecticut	10	1	C	0	.0
July 19	do	New York	9	1	C	0	.0
July 20	do	Pennsylvania	1	1	C	0	.0
Aug. 16	do	Massachusetts	53	1	C	0	.0
Aug. 17	do	Connecticut	31	1	C	0	.0
Do	do	do	51	1	C	0	.0
Oct. 8	Grass	Virginia	1	7	C	0	.0
Oct. 13	Alfalfa	Illinois	1	1	C	0	.0
Oct. 14	Grass	Missouri	2	1	C	0	.0
Oct. 15	Alfalfa	Kansas	10	1	C	0	.0
Oct. 19	Bluegrass	Indiana	1	1	C	0	.0
Total or average			[2] 465	75		1	1.3
1936							
Apr. 20	Bluegrass	Ohio	1	4	{ 1B 3C }	0	0.0
Apr. 29	Rye	Virginia	1	6	C	0	.0
Apr. 30	?	North Carolina	1	1	C	0	.0
May 7	Various	Indiana	1	1	C	0	.0
May 13	Corn	do	1	1	C	0	.0
May 26	do	Virginia	1	2	C	0	.0
Do	Red clover	New York	2	1	C	0	.0
Do	Alfalfa	do	1	1	C	0	.0
May 27	Corn	do	1	1	A	1	100.0
July 23	do	Virginia	1	1	C	0	.0
Do	do	do	1	1	C	0	.0
July 29	do	Pennsylvania	1	1	C	0	.0
Aug. 26	do	New York	5	2	2B	0	.0
Sept. 8	do	Ohio	1	1	C	0	.0
Oct. 6	Rye	New York	1	1	A	1	100.0
Nov. 2	?	Virginia	2	1	C	0	.0
Total or average			[2] 36	26		2	7.6
1937							
Jan. 10		Virginia	1	6	C	0	0.0
Jan. 28	Grass	Indiana	1	1	C	0	.0
Apr. 21	do	Virginia	1	3	C	0	.0
May 13	Corn	North Carolina	1	1	C	0	.0
May 29	Sweet corn	New Jersey	1	6	C	0	.0
Do	Field corn	Maryland	1	1	C	0	.0
June 9	Sweet corn	New Jersey	1	4	{ 1A 1B }	1	25.0
July 8	Field corn	do	30	1	C	0	.0
July 19	Sweet corn	Indiana	1	1	C	0	.0
July 21	do	do	1	1	C	0	.0
July 22	Grass	New Jersey	1	32	{ 2A 4B }	2	6.2
Aug. 17	Grassy corn	Pennsylvania	10	4	C	0	.0
Aug. 18	Sweet corn	New York	4	1	C	0	.0
Aug. 19	do	do	6	1	C	0	.0
Aug. 20	Corn	do	10	4	C	0	.0
Do	do	do	8	1	C	0	.0
Do	Field corn	New Jersey	1	1	C	0	.0
Sept. 2	Sweet corn	New York	1	11	6A	4	36.3
Sept. 18	Grass	Ohio	1	10	6B	1	10.0
Sept. 23	do	New Jersey	1	26	4B	1	3.8
Oct. 5	Rye	New York	1	1	C	0	.0
Total or average			[2] 233	117		9	7.6
Grand total			1,079	410		21	

[1] A=Typical colonies of *Aplanobacter stewarti;* B=atypical yellow colonies; C=no colonies.
[2] Total number of insects=insects per isolation×isolations.

Fifteen of the forty-four isolations of *Aplanobacter stewarti* from field-collected specimens of *Chaetocnema denticulata*, or 34.1 percent, were heavy seedings, as compared with about 80 percent in the case of *C. pulicaria*. The other plates contained only a few colonies of *A. stewarti* or doubtful yellow colonies. Three heavy seedings of what appeared to be *A. stewarti* produced no infection on corn, even after inoculations were repeated. Almost half of the *C. denticulata* specimens from which *A. stewarti* was isolated were collected from hosts other than corn. *C. denticulata* is not so abundant as *C. pulicaria* on corn at the Arlington farm and prefers fall panicum [13] when it is available, but it ranks next to *C. pulicaria* in number of field-collected adults from which *A. stewarti* was isolated. Apparently, *C. denticulata* does not furnish so favorable an environment for the wilt organism as does *C. pulicaria*. Possibly the organisms become less virulent when associated with *C. denticulata*.

The maximum number of *Chaetocnema denticulata* adults yielding *Aplanobacter stewarti* was obtained in 1935 in a test of 97 adults that had been confined to infected corn for 4 days before the test. Fifty-nine, or 60.8 percent, of 97 adults yielded colonies of *A. stewarti*, as compared with 47.8 percent of 23 *C. denticulata* adults under similar conditions in 1934 (*9*).

OTHER INSECTS APPARENTLY CARRYING APLANOBACTER STEWARTI

In addition to isolations from *Chaetocnema pulicaria* and from *C. denticulata*, isolations of *Aplanobacter stewarti* were made from each of 12 other species of insects collected in the field during 1934–37, in one or more instances. Whether more isolations of *A. stewarti* would have been obtained from any of the 12 species if larger numbers of each had been tested is problematical. On the basis of the results so far obtained, none of the species from which *A. stewarti* has been isolated, except *C. pulicaria* and *C. denticulata*, can be considered as vectors of any importance under field conditions. The records on the isolations of *A. stewarti* obtained from several of the species discussed in this section would not be presented had not some of these species, after being confined to infected corn in cages for several days, also yielded the wilt organism after being externally disinfected and tested in the usual way. The species involved are treated in the same order in which they are listed in table 6. It may be noted that *A. stewarti* was isolated from specimens of the smut- and pollen-feeding beetles *Phalacrus* sp., *Stilbus apicalis*, and *S. viduus*. Although *A. stewarti* has not been isolated from the pollen cells of corn, the bacteria have been found mixed with pollen and have been isolated from the anther filaments and vascular tissue of the corn tassel (*7*). Just how *A. stewarti* came to be present in these smut- and pollen-feeding beetles is not apparent, especially since very little wilt occurred in the location where the infected *Phalacrus* specimens were collected and most of the infested specimens of *S. apicalis* and *S. viduus* were collected in late fall long after corn pollen was available.

The types of cultures obtained from the 12 species, other than *Chaetocnema pulicaria* and *C. denticulata*, indicate that these species may occasionally pick up the wilt organism and carry it internally in

[13] In a previous publication (*9*), fall panicum (*Panicum dichotomiflorum Michx.*) was incorrectly referred to as Johnson grass (*Sorghum halepense* (L.) Pers.).

small numbers, but the high proportion of atypical colonies suggests unfavorable environmental conditions for the bacteria in these insects.

CHAETOCNEMA CONFINIS [14]

During the 4-year period 1934–37, 238 isolations were made from 1,289 adults of *Chaetocnema confinis* and only 4 isolations of *Aplanobacter stewarti* were obtained. These records were made during 1934 and 1935, when identifications of this species were not so accurately made as in 1936 and 1937, and it seems quite probable that this species was confused with *C. pulicaria* during the early part of the work. From the records obtained it would appear that *C. confinis* is not a vector of *A. stewarti* under field conditions. In feeding tests, however, in which adults were confined to infected corn in cages for several days and then tested by isolation in the usual manner, 48 isolations from 128 adults of *C. confinis* yielded 6 cultures of *A. stewarti* during 1935 and 1936, indicating that this species did pick up the organism and carry it internally, for a short time at least, under the conditions of these tests. On the plates poured from suspensions of *C. confinis*, there were either a few typical colonies of *A. stewarti* or atypical yellow colonies that upon inoculation into corn proved to be *A. stewarti*. Most of the cultures contained nothing resembling the wilt organism. All attempts to inoculate healthy corn by means of adults of this species, that had been confined to infected corn for several days, were unsuccessful.

DIABROTICA DUODECIMPUNCTATA [15]

Diabrotica duodecimpunctata has long been considered important as a vector of *Aplanobacter stewarti* in the field, but if one may judge from the data obtained during the 4-year period 1934–37, its importance has been overestimated. The writers have not previously confirmed direct summer dissemination of *A. stewarti* by *D. duodecimpunctata* as reported by Rand and Cash (*10, p. 30*), but have reported transmission of *A. stewarti* from infected to healthy corn only when the insects were confined in cages (*9*). Not until 1935 was the wilt organism isolated from field collections of adults of *D. duodecimpunctata*, when 54 isolations, made from 322 field-collected individuals, yielded 3 cultures of *A. stewarti*. During 1934, 20 isolations were made from 178 field-collected adults, which yielded no *A. stewarti*, and during 1936 and 1937, 40 isolations, made from 138 field-collected *D. duodecimpunctata*, yielded no *A. stewarti*. During the 4-year period 1934–37, a total of 114 isolations were made from 638 field-collected *D. duodecimpunctata*, and these yielded only 3 cultures of *A. stewarti*. In addition, 13 isolations made from 14 adults of *D. duodecimpunctata* that had fed on infected corn in cages for several days during 1934 and 1935 yielded no *A. stewarti*. These data indicate that this species is not an important factor in the dissemination of bacterial wilt of corn under field conditions. On the plates poured from broth suspensions of *D. duodecimpunctata*, only a few colonies of *A. stewarti* developed in mixed cultures.

DISONYCHA GLABRATA [16]

One isolation from two individuals of *Disonycha glabrata* collected from infected corn at the Arlington farm, August 10, 1934, yielded

[14] Coleoptera, Chrysomelidae.
[15] Coleoptera, Chrysomelidae.
[16] Coleoptera, Chrysomelidae.

Aplanobacter stewarti. Plates poured from broth suspensions of this species showed light seedings of the wilt organism. This insect apparently is rarely found on corn, and these specimens may have been swept from *Amaranthus* sp. present in the corn field. Further studies are necessary to determine its status as a vector of *A. stewarti*.

EPITRIX CUCUMERIS [16]

During the 4-year period 1934–37, 121 isolations were made from 1,150 adults of *Epitrix cucumeris*, and 3 isolations of *Aplanobacter stewarti* were obtained during 1935 and 1936. The isolation of *A. stewarti* from this species during 1935 was obtained from 1 adult collected from oats near Burlington, N. J., on May 16. In 1936, 1 isolation of *A. stewarti* was obtained from 10 individuals and 1 from 7 individuals, all collected from sweet corn at Selinsgrove, Pa., May 25. One of the plates poured from adults of *E. cucumeris* had a light seeding of *A. stewarti*, but the other two showed only a few yellow colonies that were not typical.

PHALACRUS SP.[17]

During 1936 and 1937, 34 isolations were made from 121 adults determined as *Phalacrus* sp. One culture of *Aplanobacter stewarti* was obtained from a broth suspension of 5 adults collected on corn at Geneva, N. Y., August 28, 1937. The plates showed a heavy seeding of typical colonies of *A. stewarti*. No explanation is offered for an isolation of *A. stewarti* from a smut- and pollen-feeding beetle collected at a point where very little wilt occurred. No further tests have been made with this species.

STILBUS APICALIS [18]

During the 4-year period 1934–37, 20 isolations were made from 148 individuals of *Stilbus apicalis* and 2 isolations of *Aplanobacter stewarti* were obtained, one from 2 individuals collected from infected corn at the Arlington farm, September 5, 1934, and the other from 2 individuals collected from alfalfa at the Arlington farm, November 5, 1935. The plates poured from these latter 2 adults of *S. apicalis* gave mixed cultures of various organisms, but 1 atypical yellow colony was transferred which on inoculation into corn produced typical symptoms of bacterial wilt. No *A. stewarti* culture was obtained from 4 isolations made from 16 adults of *S. apicalis* that were confined to infected corn in cages for several days during 1935 and 1936. The above-mentioned isolation of *A. stewarti*, from a second pollen-feeding beetle, was made in the late fall.

STILBUS VIDUUS [18]

During the 4-year period 1934–37, 45 isolations were made from 225 adults of *Stilbus viduus* and 1 isolation of *Aplanobacter stewarti* was obtained. This isolation was from 4 individuals collected from alfalfa at the Arlington farm, November 5, 1935. The plates poured from suspensions of 4 adults of *S. viduus* were similar to those already described for *S. apicalis*. As in the case of *S. apicalis*, this isolation of *A. stewarti* from a third pollen-feeding beetle also was made in late fall. In feeding tests to determine whether this insect would pick up the organism and carry it internally for a few hours at least, no culture of *A. stewarti* was obtained from 5 isolations made from

[16] Coleoptera, Chrysomelidae.
[17] Coleoptera, Phalacridae.
[18] Coleoptera, Phalacridae.

35 adults confined to infected corn for several days in cages during 1936.

NABIS FERUS[19]

During the period 1934–37, 11 isolations were made from 28 adults of *Nabis ferus*. One isolation of *Aplanobacter stewarti* was obtained from 6 adults collected at the Arlington farm, April 16, 1936. One atypical yellow colony from a mixed culture produced wilt in corn. Seven isolations made from 42 individuals that had been confined to infected corn in cages for several days in 1935 and 1936 yielded no *A. stewarti*. Although *N. ferus* is considered a predatory insect, after it had been starved for a few hours it was observed to puncture succulent corn leaves and suck the juices from them; so it would be entirely possible for this species to carry the wilt organism internally. No explanation is offered for an isolation of *A. stewarti* from this insect collected April 16, before any infected corn plants were available in the field.

ILLINOIA SOLANIFOLII[20]

Fifty-nine isolations were made from a total of 415 individuals of *Illinoia solanifolii* during 1934 and 1935, and 1 isolation of *Aplanobacter stewarti* was obtained. This record was secured during 1934 from a collection of 48 individuals of this species made from an infected sweet corn plant at Burlington, N. J., on July 17. An atypical yellow colony produced wilt in corn. Additional tests were conducted in 1936, when 25 isolations were made from 250 individuals that had been confined to infected corn in cages for several days. No *A. stewarti* was obtained, and these comparatively meager data would indicate that this species is not an important vector of bacterial wilt of corn under field conditions.

STIRELLUS BICOLOR[21]

During 1934 and 1935, three isolations were made from seven individuals of *Stirellus bicolor*. In 1934 a light seeding of *Aplanobacter stewarti* was obtained from one isolation from four adults collected from infected sweet corn at the Arlington farm, August 10. This species is not commonly found on corn and no further tests were made with it, except that one adult which had been confined to infected corn for several days during 1935 was found to yield no *A. stewarti* when tested in the usual manner.

THAMNOTETTIX NIGRIFRONS[21]

During the period 1934–36, 13 isolations were made from 221 adults of *Thamnotettix nigrifrons*. In 1934, 1 isolation, made from a collection of 26 adults from infected sweet corn at the Arlington farm, August 10, yielded *Aplanobacter stewarti*. Three typical yellow colonies of *A. stewarti* developed in a plate of white colonies. One isolation made from 9 adults that had been confined to infected corn for several days during 1935 yielded no *A. stewarti*.

ANAPHOTHRIPS OBSCURUS[22]

During the 3-year period 1934–36, 23 isolations were made from 603 individuals of *Anaphothrips obscurus*. One isolation of *Aplano-*

[19] Hemiptera, Nabidae.
[20] Homoptera, Aphididae.
[21] Homoptera, Cicadellidae.
[22] Thysanoptera, Thripidae.

bacter stewarti was obtained from a collection of 17 individuals (not disinfected externally) found on an infected sweet-corn plant at Hempstead, N. Y., May 29, 1936. The plates showed a heavy seeding of atypical yellow colonies. No feeding tests on infected corn were made with this species, and its importance as a vector of *A. stewarti* under field conditions is undetermined.

ADDITIONAL TESTS

Since *Aplanobacter stewarti* had been isolated from field collections of several species of insects, most of the species discussed earlier in this paper and many others were confined to infected corn in cages for several days and then tested in the usual manner to determine which species might pick up the organism under such conditions. The species used in these tests are included in table 6 and are designated by footnote 3 of that table. In many instances, only a few individuals of a species were used for isolation after feeding on infected corn. It was very difficult to keep infected corn plants in a suitable condition to be fed upon for several days by large numbers of insects confined in cages, and some of the species lived but a short time under these conditions.

Species tested but not included in table 6, were *Graphocephala versuta* (Say), *Hysteroneura setariae* (Thos.), *Anthonomus* sp., *Frankliniella williamsi* Hood, and *Peregrinus maidis* (Ashm.). Tests of probable significance were conducted with the following species, the results of which have not been reported earlier in this paper: 9 isolations from *Aphis maidis* made from 142 individuals; 3 isolations from *Agallia constricta* made from 28 individuals; 19 isolations from *H. setariae* made from 410 individuals; 2 isolations from *P. maidis* made from 41 individuals; 3 isolations from *F. williamsi* made from 80 individuals; 3 isolations from *Lygus pratensis oblineatus* (Say) made from 124 individuals. *Aplanobacter stewarti* was not obtained from any of these species.

BACTERIAL WILT ON CORN RELATIVES

Included with *Zea mays* in the tribe Tripsaceae are the closest wild relatives of corn, *Euchlaena*, or teosinte, and *Tripsacum*, or gamagrass. *Zea mays* and *E. mexicana* Schrad. cross freely, and the hybrids are fertile. *E. perennis* Hitchc., the perennial species, crosses less readily with corn, and the hybrid plants are usually sterile.

Euchlaena mexicana, the annual species, has been found (*3*) to be susceptible to natural infection with bacterial wilt in the field and to inoculation in the greenhouse by means of pure cultures or by feeding of infested corn flea beetles. The Florida form was the one observed and tested. This form has been reported (*1*) as producing less fertile hybrids with corn than other forms of the annual species. Inoculations of three plants of *E. perennis* in the greenhouse, by introducing pure cultures of *Aplanobacter stewarti* into the leaf and base of the stalk, showed that this species also is susceptible to wilt infection. Young plants, 10 to 12 inches high, developed long water-soaked streaks and general wilting. One plant was dead a week after inoculation. Another, with a long wilt streak the length of one leaf, outgrew the infection. Seven plants of *E. perennis* were grown in the field at Arlington farm next to heavily infected sweet corn, during the 1937

season. Local leaf lesions developed from natural infection on all of these plants.

Tripsacum is the next closest but much more distant relative of corn (*2*). Crosses with corn have only recently been made by using corn as the female plant, and the plants were sterile. Hitchcock (*6*) lists three species of *Tripsacum* as native to the United States. Two of these, *T. dactyloides* (L.) L. and *T. lanceolatum* Rupr. have been tested for susceptibility to wilt along with two other species with broader leaves, *T. pilosum* (Scribn. and Merr.) from Amparo, Mexico, and *T. latifolium* Hitchc. from Honduras.[24] *T. dactyloides* is widely distributed over the eastern part of the United States and grows wild at the Arlington farm and in other nearby places. No bacterial wilt lesions have ever been found on any of these wild plants on or near the Arlington farm, although they were under observation for 4 years 1934–37.[25] Eighteen field inoculations of young growing shoots of these plants failed to produce any wilt symptoms. No wilt symptoms developed on either the Kansas or Maryland forms of *T. dactyloides* from six inoculations of each in the greenhouse. Nor did any lesions develop on *T. dactyloides* in 1935 after apparently infested adults of *Chaetocnema pulicaria* confined in cages in the greenhouse had fed on the leaves. Seven inoculations each of young shoots and leaves of *T. lanceolatum*, *T. latifolium*, and *T. pilosum* in the greenhouse failed to produce any wilt symptoms. During the 1936 and 1937 growing seasons two plants each of *T. lanceolatum*, *T. latifolium*, and *T. pilosum* were grown at the Arlington farm next to plots of infected sweet corn. These grew into large spreading plants 5 to 6 feet tall with many shoots and leaves. During both seasons *C. pulicaria* was observed feeding on all three species of *Tripsacum*, and old feeding injuries were numerous. No wilt lesions could be found, however, on any of these plants, and no wilt developed from eight inoculations made on young leaves and shoots of each species in 1936. The hybrid *Tripsacum dactyloides* × *Zea mays* and plants of the corn parent have been tested by inoculation in the greenhouse. The corn parent was moderately susceptible to wilt. Typical wilt lesions developed throughout the length of the inoculated leaves of six plants. These leaves died, but the plants continued to grow normally without further evidence of wilt, although pure cultures of the wilt organism had been introduced into the stem. Ten plants of the corn parent were grown in the field at the Arlington farm beside infected sweet corn during the 1937 season. All of these plants developed local wilt lesions on the outer halves of the leaves. Inoculations in the greenhouse of the one hybrid plant available produced no wilt symptoms. On June 10, 1937, this hybrid was planted in the field beside susceptible sweet corn. Insect-feeding injuries were observed during the season, and by the middle of September reddish-brown streaks one-fourth of an inch long on the leaves were found to contain abundant bacteria. Three isolations from these lesions gave typical colonies of *Aplanobacter stewarti*, which, on inoculation, produced wilt in susceptible sweet corn in the greenhouse. These lesions had apparently developed from insect-feeding injuries and did not increase further in size.

[24] Plants furnished by J. H. Kempton, Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.

[25] *Tripsacum dactyloides* was later reported to be a native host of *Aplanobacter stewarti* by Elliott and Robert (*5*).

Three Old World genera—*Coix*, *Sclerachne*, and *Polytoca*—belonging to the tribe Tripsaceae have been tested in the greenhouse and field. *Coix lacryma-jobi* L. has previously been reported as a host for *Aplanobacter stewarti* when inoculated in the greenhouse (*9*). During the summer of 1935, 4 plants each of 3 varieties of *C. lacryma-jobi*,[26] namely, Lackfoo, Glutinous, and wild, were grown in the field at the Arlington farm next to infected sweet corn. No inoculations were made, but *Chaetocnema pulicaria* fed on the leaves throughout the season and typical long wilt streaks developed. During the 1936 season 4 plants each of *Sclerachne punctata* R. Br. and *Polytoca barbata* Stapf[27] and, in 1937, 36 plants of *S. punctata*[28] were grown at the Arlington farm next to heavily infected sweet corn. Individuals of *C. pulicaria* were observed feeding on these plants, and although feeding injuries were abundant on the leaves no wilt lesions developed and no bacteria could be found in or around the feeding injuries. Ten inoculations were made on young leaves and shoots of each species in 1936. The only evidence of any infection was a reddening of the veins of an inoculated leaf of *Sclerachne* for several inches beyond the leaf injury. Two inches below the point of inoculation the veins were full of bacteria. *A. stewarti* was reisolated and produced wilt on corn. The lesion was slight, however, and the infection did not progress further. Later in 1936, 2 sets of 4 inoculations each were made on young shoots of *Polytoca* and *Sclerachne* in the greenhouse. No wilt symptoms developed on the young shoots of the former. The inoculated shoots and leaves of *Sclerachne* dried and died. The leaf veins and fibrovascular bundles of the stalk were full of bacteria, and *A. stewarti* was reisolated from both. As stated above, no natural infection developed in the field the following summer.

The next tribe, the Andropogoneae, is not widely separated from the Tripsaceae (*2*). The various forms of maize completely bridge the gap between the two tribes. Two genera of considerable economic importance, *Saccharum officinarum* L. and *Sorghum vulgare* Pers. (*Holcus sorghum* L.) have been tested for susceptibility to wilt by the senior author and by other investigators.

In 1935 Ivanoff (*8*) reported that inoculations in the greenhouse on *Sorghum vulgare*, varieties Waconia (Rox) Orange sorgo, Blackhull kafir, darso, Dwarf Yellow milo, Kansas Orange sorgo, Gooseneck sorgo, and Red Amber sorgo, produced reddening of infected veins and in some cases yellowing of the leaf tissue outside the red areas. *Aplanobacter stewarti* was reisolated from these lesions. No leaf symptoms resulted from 2 inoculations in the field of over 1,000 plants of Waconia Orange sorgo and Kansas Orange sorgo. Red bundles appeared in the stalks of Waconia Orange but not in Kansas Orange. In 1 series of field inoculations on 300 Sudan grass plants, "only a small percentage of the plants showed any symptoms" and "these symptoms were not considered striking." In another set of inoculations symptoms were similar to those on corn. Ivanoff was not able to produce any infection in 25 inoculated sugarcane plants.

Similar tests for susceptibility to bacterial wilt have been carried on by the senior author in the greenhouse and in the field at the

[26] Seed from the Plant Pathology Laboratory, Bureau of Plant Industry, Manila, P. I.
[27] Seed from Dr. Paul Weatherwax. Grown on campus of Indiana University, 1935; original seeds from Poona, India.
[28] Seed from Dr. Paul Weatherwax, Indiana University. Grown at Bloomington, Ind., 1935; original seed from Buitenzorg, Java.

Arlington farm. The following genera and species were inoculated in the greenhouse: *Sorghum halepense* (L.) Pers. (Johnson grass); *S. vulgare sudanense* (Piper) Hitchc. (Sudan grass); certain commercial varieties of *S. vulgare*, namely, White durra, hegari, Blackhull kafir, Dawn kafir, Blackhull kaoliang, Manchu Brown kaoliang, Standard Yellow milo, Dwarf White milo, Dwarf Yellow milo, Colman sorgo, Dakota Amber sorgo, Folger sorgo, Orange sorgo, Sumac sorgo, Black Amber sorgo, shallu, Spur feterita, Leoti Red sorgo, Fargo Straightneck milo, Evergreen Standard broomcorn, and darso; and 13 cultivated varieties of *Saccharum officinarum*,[29] namely, D–74,[30] Louisiana Purple, C. P. 807, C. P. 29–291, C. P. 28–19, C. P. 29–320, C. P. 29–116, Co. 290, Co. 281, P. O. J. 36M, P. O. J. 234, P. O. J. 213, and Uba.

No infection developed on Johnson grass or Sudan grass. All of the inoculated sorghum plants were stunted as compared with uninoculated checks, probably owing to injury. In 7 of the varieties the central shoot was killed and side shoots developed. In 8 of the varieties reddening of injured veins developed, and in 4 cases there was slight yellowing of the tissue along these veins. Isolations from such lesions on hegari gave yellow colonies which did not produce wilt in sweet corn. Isolations from red veins of 11 other varieties of sorghum gave negative results. There was also some reddening of bundles of the stalk, mostly in the inoculated internode. The sorghum plants all outgrew the effects of inoculation and produced heads, whereas the susceptible corn plants succumbed to the disease. On sugarcane slight yellowing of leaf veins developed on some of the plants, but the plants soon outgrew any symptoms of injury and bacteria were not found in the veins except about the point of inoculation.

With the exception of the sugarcane varieties, 6-foot rows of 12 plants each of the foregoing genera, species, and varieties of corn relatives were planted in the field at the Arlington farm early in June 1935, in the same plot with sweet corn, which during the season was destroyed by wilt. Inoculations of 6 plants of each variety were made in the same way as in the greenhouse, and in addition notes were taken on insect-feeding injuries and natural infection. No infections resulted from inoculations on Johnson grass. In some of the sorghums reddening of the veins and yellowing of tissue along the veins developed for an inch or two beyond the inoculation injuries; but no bacteria were isolated, the lesions did not develop further, and the plants grew normally. Corn flea beetles were abundant during the 1935 season and were observed feeding to some extent on all of the varieties tested. Throughout the season, however, no signs of wilt appeared on any of the plants. On *Euchlaena* and *Coix*, growing nearby, typical long wilt streaks developed. Bacteria were abundant in the lesions and *Aplanobacter stewarti* was isolated from both genera.

Manisuris cylindrica (Michx.) Kuntze, another of the Andropogoneae, developed no wilt symptoms from inoculations in the greenhouse or from 12 inoculations in the field. In 1936, 12 large plants and in 1937, 2 clumps of plants grew next to heavily infected sweet

[29] Plants supplied by R. D. Rands and E. Dopp, of the Division of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.

[30] The letters designating the sugarcane varieties indicate experiment stations where the varieties were developed: D=Demerara; C. P.=Canal Point, Barbados; Co.=Coimbatore; P. O. J.=Proef station Ost, Java.

corn in the field. Individuals of *Chaetocnema pulicaria* were observed feeding on the leaves, and feeding injuries were present on the outer halves of many leaves; but no natural infections developed and no bacteria could be found in or around the insect-feeding injuries.

Setaria glauca, in the Paniceae, the next tribe of the Gramineae, has been reported by Ivanoff (7) as developing white or tan stripes after inoculation in the greenhouse. Six field and four greenhouse inoculations of this species at the Arlington farm did not produce bacterial wilt symptoms.

The results of the inoculations at Arlington farm indicate that yellow bristle grass (*Setaria lutescens*), Johnson grass, Sudan grass, sugarcane, *Manisuris cylindrica*, *Tripsacum* species, *Polytoca*, and probably *Sclerachne* are not natural hosts of *Aplanobacter stewarti*, although slight reddening or yellowing of fibrovascular bundles may result from greenhouse inoculations. In the opinion of the senior author plants that show no wilt symptoms when inoculated in the field or when subjected to feeding by *Chaetocnema pulicaria* can scarcely be considered as host plants of *A. stewarti*.

Species and varieties of *Coix* and *Euchlaena* are the only ones found up to the present time at the Arlington farm that have developed typical wilt symptoms from artificial as well as natural inoculation. Of the native American genera and species, *Euchlaena mexicana*, the closest relative of corn, is the one most susceptible to infection. *E. perennis*, less closely related to corn, is somewhat less susceptible. *Tripsacum* species, the next closest relatives, have been immune to wilt in these experiments.

SUMMARY

At the Arlington Experiment Farm, near Washington, D. C., in 1934, 1935, and 1937, bacterial wilt was abundant and destructive. Sixty to eighty percent of the susceptible Golden Bantam sweet corn plants became infected in the early leaf stage, and as a result many of the plants were stunted or killed and relatively few marketable ears were harvested. The wilt situation in 1936 was quite different. There was very little infection in the early leaf stage, and although infection became general as the season advanced most of the lesions did not develop beyond local leaf infections. The time for material injury to the sweet corn crop had passed, and a good crop of marketable ears was harvested.

The mean temperature for December, January, and February, 1933–34, at Washington, D. C., was slightly below the mean normal of 35.1°, but well above 32° F. In 1934–35 the mean winter temperature was slightly above normal. In 1935–36 the winter was much colder, the average temperature falling slightly below 32°. In 1936–37 the average was above 40°.

At the Arlington farm in 1934, 1935, and 1937 adults of *Chaetocnema pulicaria* were abundant early in the season on young corn plants. In 1936, these beetles were much less abundant in May and June. By July 15 they showed a noticeable increase in numbers, and by August 15 they were abundant on the corn plants. In 1937, at the Arlington farm, adults of *C. pulicaria* again were abundant on corn early in the season.

At Geneva, N. Y., not a single wilt lesion was found in 1936, but in 1937, 11 percent of the susceptible Golden Bantam plants were

infected. In 1936 mean winter temperatures at Geneva were below 32° F., whereas in 1937 they were well above 32°. Upon three occasions (when weather conditions were not most favorable for collecting this species), no specimens of *Chaetocnema pulicaria* were found at Geneva in 1936, but late in August some evidence of feeding by this insect was observed, indicating that this species was present in small numbers at this time. Fifty-seven specimens of *C. pulicaria* were collected at Geneva in late August 1937, and 18 percent of these were found to be infested with *Aplanobacter stewarti*.

At Yonkers, N. Y., in 1935, 9 percent of the early planting of susceptible Golden Bantam plants were infected and 3 percent of these were killed. In 1936 no wilt was found by the middle of June on 700 Golden Bantam plants. By the middle of August, 4 percent were found infected. In 1937, 5 percent were infected early in the growth of the plants and 99 percent when the plants were mature or in silk.

On Long Island in 1936 there was little wilt early in the season but abundant wilt by the middle of August. Wilt records for 1937 show more early infection than in 1936. In New York City mean winter temperatures for 1936 were below 30° F. and for 1937 above 38°.

During the 4-year period 1934–37, 28,769 insects representing 94 species belonging to 76 genera, were tested for *Aplanobacter stewarti* to determine which species, and what proportion of each, carry the wilt organism internally and may be vectors of bacterial wilt under field conditions. Results obtained by testing 18,613 individuals of *Chaetocnema pulicaria* during the 4 years indicate that it is the only species of importance in harboring the wilt organism over winter and also in spreading the disease during the corn growing season.

Chaetocnema denticulata may possibly play some part in wilt dissemination, but at the Arlington farm it is not so abundant as *C. pulicaria* and it feeds preferably on panic grass. While *Aplanobacter stewarti* sometimes occurs in abundance in *C. denticulata*, which ranks next to *C. pulicaria* in numbers of adults from which *A. stewarti* has been isolated, *C. denticulata* is apparently not a close second in importance to *C. pulicaria* and it is doubtful whether the wilt organism ever overwinters in adults of *C. denticulata*.

From results obtained, none of the other species from which *Aplanobacter stewarti* has been isolated can be considered vectors of any importance under field conditions. It seems to be quite possible for insects that occasionally feed on corn to pick up *A. stewarti* from infected plants, but judging from the type of cultures obtained, these insects do not furnish a favorable environment for the bacteria and are apparently of no importance in the spread of bacterial wilt.

In the species of *Chaetocnema* the proportion of infested beetles has usually been greater when the insects were caged on infected corn than when they were collected from the field. In 1934, *Aplanobacter stewarti* was isolated from 56 to 68 percent of the *Chaetocnema pulicaria* individuals caged on infected corn and in 1935 from 60 to 95 percent: in 1934, it was isolated from 48 percent of the caged individuals of *C. denticulata* and in 1935 from 61 percent.

Further proof of the overwintering of *Aplanobacter stewarti* in hibernating adults of *Chaetocnema pulicaria* was obtained. Seven beetles collected March 16, 1936, were fed on corn plants in the greenhouse, and typical wilt symptoms developed. *A. stewarti* was isolated from *C. pulicaria* collected at the Arlington farm in every

month of the year except February during the 4-year period, and one isolation was made from beetles collected February 26, 1936, at Norfolk, Va.

Early- and late-season isolations from *Chaetocnema pulicaria* from other localities have shown that overwintering adults of *C. pulicaria* are more or less infested with *Aplanobacter stewarti* in all sections of the country where wilt is prevalent and isolations have been made.

In studies of the host range of *Aplanobacter stewarti*, inoculations in the greenhouse on rapidly growing young plants may cause stunting and some discoloration along the veins. If, however, such lesions or discolorations do not progress and if new shoots can develop and grow normally without further evidence of infection, such plants should be tested further by being subjected to natural infection in the field. If these plants, growing under natural conditions in the field next to heavily infected sweet corn and injured by feeding of adults of *Chaetocnema pulicaria* which were spreading the infection on corn and many of which were undoubtedly infested, show no signs of bacterial wilt they can scarcely be considered hosts for the bacterial wilt organism. *Euchlaena perennis*, in addition to *E. mexicana* and *Coix lacryma-jobi* already reported, was found to be susceptible to infection with the wilt organism. *Tripsacum dactyloides*, *T. pilosum*, *T. lanceolatum*, and *T. latifolium* were immune to wilt in these experiments. Other genera and species tested did not develop typical wilt symptoms.

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GENETIC AND CYTOLOGIC STUDIES OF A BRACHYTIC MUTATION IN BARLEY[1]

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INTRODUCTION

Studies of the action of genes from the time they enter the gametes until they produce their final effects on the characters of mature individuals are still in an elementary state of development. Genes having a marked effect on size characters furnish excellent material for studies of this nature, especially if a single gene may be studied by itself.

In 1929 genetic studies were begun at the Minnesota Agricultural Experiment Station on a dwarf barley which had arisen spontaneously as a mutation in a plot of Himalaya barley grown by Dr. L. J. Stadler at the Missouri Agricultural Experiment Station. Dr. F. J. Stevenson, then in charge of barley genetics at the Minnesota station, began these studies for the purpose of determining the linkage relationships of the gene producing the dwarfed condition.

In correspondence with Stevenson, Stadler described the mutation as follows: "A shortened plant with short leaves, short awns, and short internodes, something like brachytic corn but far less extreme. It is distinct enough to be easily separated, and equal in viability to the normal." Aside from its shortened appearance, the mutation is very similar to Himalaya, which is a six-rowed, rough-awned, and hulless variety, grown commercially to some extent in the western part of the United States. The new dwarf was given the name Brachytic, and the notation *br* has been used by Powers (*28*)[3] for the gene. A comparison of the general appearance of Brachytic and Himalaya is shown in figure 1.

The studies were continued later by Powers (*28*), who reported on the mode of inheritance of the brachytic character. The studies reported in this paper on the cytological and histological nature of the brachytic character were suggested by Powers in 1932, and the data on the linkage relationships of the brachytic gene were turned over to the writer by Powers in 1935.

The following considerations are presented in this paper: (1) Further studies on the inheritance of the brachytic habit of growth; (2) the linkage relationships of the gene for brachytic; (3) the cytological nature of the mutation, whether it is the result of a gene

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[3] Italic numbers in parentheses refer to Literature Cited, p. 711.

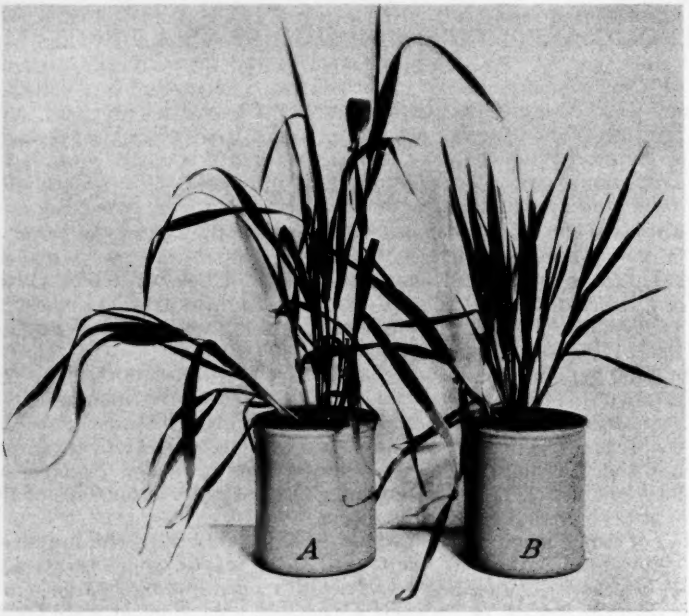

FIGURE 1.—Comparison of plants of Himalaya (*A*) and Brachytic (*B*).

mutation or a chromosomal change; and (4) the nature of the action of the brachytic gene with respect to plant and organ size, cell size and number, growth rate, and frequency of cell division.

REVIEW OF LITERATURE

THE INHERITANCE OF SIZE CHARACTERS

The classic work on genes affecting plant size is that of Keeble and Pellew (*15*), who showed that two factors were involved in differentiating between a short and a very tall race of peas. In general, size characters have been found to be affected by several or a large number of factors, according to the multiple-factor hypothesis advanced by Nilsson-Ehle (*26*) and East (*5*). However, a few size characters, determined by only one or a few genes, have been studied in plants.

Linkage between factors for quantitative or size characters and factors for qualitative characters has been demonstrated by Sax (*32*) and Sirks (*38*) in beans, Lindstrom (*20*) in tomatoes, and Kempton (*16, 17*) in maize. The character studied by Kempton was a brachytic variation, similar in behavior to the brachytic character in barley which is being discussed in this paper. Similar types of linkage in barley have been reported by Griffee (*11*), Neatby (*25*), Wexelson (*43, 44*), and Powers (*28*), and suggested by Robertson and Austin (*30*).

LINKAGE RELATIONSHIPS IN BARLEY

The literature on linkage relationships in barley has been reviewed extensively in a recent paper by Robertson (*29*). It therefore seems unnecessary to review it further than to state that, according to Robertson, all of the expected seven linkage groups have been established and that three or more factors have been located in each group. Powers (*28*) showed that the factor pair for normal vs. brachytic habit of growth (*Br br*) was independent of the factor pairs for non-six-rowed vs. six-rowed spike (*V v*) and black vs. white lemma and pericarp (*B b*) in the first and second linkage groups, respectively.

MEIOSIS AND CHROMOSOME NUMBER IN BARLEY

As far as the writer is aware, no detailed studies have been made of meiosis in barley. Griffee (*11*) found that the somatic chromosome number was 14 in cultivated barleys. His counts have been substantiated by Griffee (*12*) and Aase and Powers (*1*).

CELL SIZE IN RELATION TO PLANT AND ORGAN SIZE

The literature pertaining to the relationship of cell size to organ and body size in both plants and animals has been reviewed in detail by Bailey and Tupper (*2*). Sinnott (*36*) also has presented a comprehensive review of studies on cell size and shape in plants.

The relationship of cell size to dwarfism or nanism has been investigated by Gauchery (*7*) and Sierp (*35*). Gauchery concluded that dwarfs often have smaller calls but that different tissues react very differently to conditions inducing dwarfism. Sierp called attention to the necessity of distinguishing between depauperate plants and true constitutional dwarfs. The former have smaller cells than normal. He recognized three classes of inherited dwarfing: dwarfs of *Pisum*, *Solanum*, *Zea*, and *Clarkia*, having smaller cells than normal; *Nigella*, larger than normal; and *Mirabilis* and *Lathyris*, normal.

GROWTH RATES AND GENETIC FACTORS

According to Sinnott and Dunn (*37*), differences in size may be correlated with differences in rate of growth, length of the growth period, or both. Goldschmidt (*9*) has postulated factors which determine the rate at which developmental processes occur and has recently (*10*) discussed this subject in more detail.

MATERIALS AND METHODS

INHERITANCE OF THE BRACHYTIC CHARACTER

Data on the inheritance of the brachytic character were taken from all the crosses used in determining the linkage relationships of the brachytic gene. A small F_2 population of Brachytic $\times$ Himalaya also was studied.

LINKAGE RELATIONSHIPS OF THE GENE FOR BRACHYTIC (*br*)

Six varieties and strains were crossed with Brachytic in order to test for linkage of the brachytic gene in all of the seven linkage groups. These varieties and strains with the characters studied and the years and generations in which the studies were made are presented in

table 1. With respect to the characters used, the genotype of Brachytic then would be *vv bb nn kk OO* X_c X_c F_c F_c.

The crosses with B1, B3, B4, and Orange Lemma had been made in 1930 and 1931 by F. J. Stevenson and L. R. Powers, and were classified and studied by the latter in the F_2 generation with the aid of the writer. The cross with B1 was subjected to an F_3 progeny test by Powers in 1934. The crosses with Colsess IV and Colsess V, obtained from D. W. Robertson of the Colorado Agricultural Experiment Station, were made in the greenhouse in 1933, and the F_1 generation was grown in the field during the summer of the same year. When an association was found in 1934 between the brachytic gene (*br*) and the dominant normal allel (F_c) of the chlorina gene in Colsess V, 130 F_2 plants of this cross were saved for an F_3 population in 1935 on the basis of the genotype exhibited in the F_2 generation.

TABLE 1.—*Contrasting characters and varieties or strains used to test for the linkage relationships of the gene for brachytic* (*br*)

Contrasting character	Symbol	Linkage group	Variety or strain	Generation and year
Non-six-rowed spike	*V*	I	B1	F_2, 1932; F_3, 1934.[1]
			B3	F_2, 1932.[2]
			B4	F_2, 1931 and 1933.
Black lemma and pericarp	*B*	II	B1	F_2, 1932; F_3, 1934.[1]
Covered caryopsis	*N*	III	B3	F_2, 1932.[2]
			B4	F_2, 1931 and 1933.
			Orange lemma	F_2, 1932.
Hooded lemma	*K*	IV	B3	F_2, 1932.[2]
Orange lemma	*o*	V	Orange lemma	F_2, 1932.
Xantha seedlings	x_c	VI	Colsess IV (heterozygous)	F_2, 1934.
Chlorina seedlings	f_c	VII	ColsessV	F_2, 1934; F_3, 1935.

[1] Reported by Powers (*28*).
[2] From unpublished data of Powers and Swenson.

All characters except xantha and chlorina seedlings were classifiable in the laboratory. Xantha seedlings were counted as soon as they emerged since they died soon after emergence. Chlorina seedlings were marked in the field by placing stakes close to the seedlings when they emerged since the chlorina character is often difficult to classify when the plants become more mature. In the crosses of Colsess IV and Colsess V with Brachytic, the classification of the brachytic character also was made in the field.

COMPARISON OF CHROMOSOME BEHAVIOR AND NUMBER IN BRACHYTIC AND NORMAL STRAINS OF BARLEY

Three F_1 plants from the cross B4 × Brachytic and one F_1 plant from the cross Brachytic × Himalaya were available for cytologic studies in 1932 and 1934 respectively. Spikes with anthers containing the various stages of meiosis were killed in acetic alcohol and transferred after 12 hours to 70 percent alcohol, according to the method outlined by McClintock (*21*). Preparations were made by the acetocarmine smear method as described by McClintock (*22*, *23*).

In 1932 seed from 24 F_2 plants of B4 × Brachytic and from the parents was space-planted in 6-foot rows to facilitate individual plant studies. Cytological material was taken at random from one row of each parent and from three different F_3 lines—homozygous normal, homozygous brachytic, and heterozygous normal × brachytic. Individual florets with anthers containing the various stages of meiosis

were isolated, special attention being paid to the quartet stage. The florets were killed and fixed in Allen's modification of Bouin's solution and embedded in paraffin blocks according to the schedule outlined by LaCour (*18*). Sections were cut 12.5 μ. thick and stained by Newton's gentian-violet method. Several florets from the same plant were embedded in the same block and oriented so longitudinal sections of the anther could be made. This provided a larger amount of material in side view which facilitates the examination and counting of the young microspores (*27*).

Seed from 1932 plants selected on the basis of high and low frequency of micronuclei was planted in 1933 and cytological material taken as in 1932. Similarly, in 1934 high and low selections from 1933 were grown, but instead of embedding and cutting, entire spikes were killed in acetic alcohol and transferred to 70-percent alcohol, later to be studied by the smear method. Himalaya from seed furnished by Stadler was added to the study for comparison with Brachytic in 1933.

The counts of micronuclei were in nearly all cases made on immature microspores grouped in quartets. In a few plants, however, the microspores had broken apart, but since the nuclear material stained well, they could be studied quite readily. Microspores through which the knife had passed were ignored and only micronuclei embedded in cytoplasm were included in the counts. One thousand microspores were counted in each plant.

COMPARISON OF HIMALAYA AND BRACHYTIC

Himalaya, the variety from which Brachytic arose, has been used in all the comparisons made for the purpose of determining the nature of the effect of the brachytic gene on the brachytic character. In so doing, it has been possible to compare Brachytic directly with its progenitor.

Gross morphological characters.—Twenty-five plants of each strain, grown under comparable conditions in 1933, were selected for comparison of length of awns, weight of seed, number of seeds, and weight per seed. Five plants of each strain were selected for comparisons of height of plants, distance between ligules, and length of leaves.

Size of plants, organs, and cells in plants growing in the field.—In 1933, two pairs of comparable plants of Himalaya and Brachytic were collected on June 14 and June 20, respectively, and preserved in the formalin acetic alcohol solution described by Chamberlain (*4, p. 21*). Measurements were made of total length of different parts, number and length of epidermal cells in different parts, and number and length of parenchyma cells in the culm (fig. 2, *A, B, C, D*). By dividing the total length of a part by the total number of cells from end to end, it was possible to ascertain the mean length of the cells. This method also provided a more or less absolute comparison of the total number of cells in plants of the two varieties.

Pairs of comparable leaves from Himalaya and Brachytic were collected from time to time and preserved in formalin acetic alcohol. Eight pairs of these leaves were later measured for length and width of blade and for length and width of upper epidermal cells (fig. 2, *C*).

Leaf width was determined by taking measurements at three different points along the leaf; the first just above the ligule, the second at the widest point of the leaf, and the last about 1 cm. from the tip. These points have been designated as the basal, middle, and terminal

regions, respectively. Cells in the stomatal zones were the most clearly defined and therefore were selected for measurement (fig. 2, *C*). Cell length was determined by counting the number of cells involved in spanning the diameter of a microscopic field provided by a 10 × objective with 12.5 oculars and converting to μ by dividing the diameter of the field by the number of cells. Three determinations were made at each of the three points where leaf width was measured, the mean of the three serving as the final value for each point. Cell width was obtained from the mean width of 10 cells in the stomatal

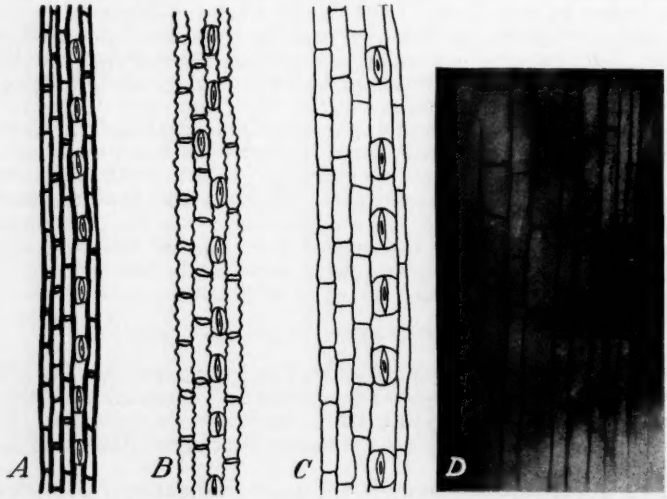

FIGURE 2.—*A*, *B*, *C*, Epidermal cells in the internode, leaf sheath, and upper epidermis of the leaf respectively, × 75; *D*, parenchyma cells in the internode of the culm, × 150.

zones at each of the three points, as measured by the eyepiece micrometer.

Staining was found to be unnecessary in making the above studies. Keeping the material soaked on the slide with 50-percent alcohol rendered it satisfactory for clear definition of the cells.

Size of organs and cells in the plumules and primary roots.—Seeds of Himalaya and Brachytic were arranged on a blotter as shown in figure 3 and allowed to germinate in a germinating oven held at 70° F. Beginning on the second day, material was taken daily on 5 successive days from different rows on the blotter. This provided 3 plants of each variety on each day. On the second day, only primary roots were available, but from the third day on, plumules also could be taken from the same plants. Length measurements were made and segments about 8 mm. long were cut from the middle and terminal regions of the root and from the basal, middle, and terminal regions of the plumule. The segments from the basal and middle regions of the plumule provided material from both the coleoptile and primary leaf whereas the terminal segment included only the primary leaf.

The segments were killed and fixed in Navaschin's fluid (*18*) and cut into paraffin sections 10 μ thick. Satisfactory staining of both the chromatin material and the cell walls was accomplished by using gentian violet followed by a 1-percent aqueous solution of Congo red

ROW	COLUMN		
I	H : B	H : B	H : B
II	B : H	B : H	B : H
III	H : B	H : B	H : B
IV	B : H	B : H	B : H
V	H : B	H : B	H : B
VI	B : H	B : H	B : H

FIGURE 3.—Arrangement of seed on the blotter for comparing length of plumule and primary root in relation to cell size and frequency of mitosis in Himalaya (H) and Brachytic (B).

Measurements of cell length, taken as in the leaves, were made in the coleoptiles and primary leaves of 12 plants of each variety (fig. 4, *A, B*). This represents 4 different rows (dates), 3 plants of each variety per row. For the coleoptile a 10 × objective was used, whereas in

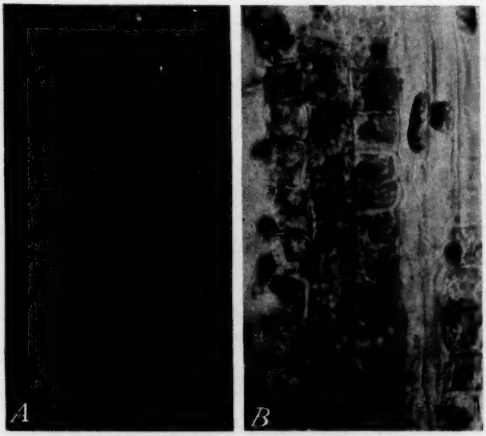

FIGURE 4.—*A*, Parenchyma cells in the coleoptile and primary leaf, × 125; *B*, parenchyma cells in the primary leaf, × 1,125.

the primary leaf, which has much smaller cells, a 90 × oil-immersion objective was found most suitable. The mean cell length from 10 sections in each of the regions was used as the final value for the region.

Nine plants representing three different rows (dates) for each variety were used in studies of the primary roots. Cell width was determined

by measuring the width of the root in longitudinal section and dividing by the number of rows of cells across the root. Means based on five sections from each region were used as final values. Cell length in the middle region was obtained as in the coleoptile except that only five sections were used. In the root tip a cell-number gradient was obtained by counting the number of cells spanning the microscopic field beginning at the tip and progressing back, 1 field at a time for a distance of 12 fields. Three such determinations were made in each of the five sections per plant with a 45 × objective and 12.5 oculars, the mean of the 15 determinations serving as the final value of each plant.

Daily growth increments.—The five plants used for the comparison of gross morphological characters of Himalaya and Brachytic also were measured for the purpose of determining the relative daily growth increments of the two strains. Measurements of height up to the tip of the upper leaf were taken at 2- to 6-day intervals from May 20 to June 20.

Frequency of mitosis.—The root tips were studied further for frequency of mitosis in the meristematic region. All stages of mitosis were counted in the five sections of each plant where the cell number gradient was determined. Length of the meristematic region was calculated from the number of microscopic fields traversed to include its length whereas width was measured directly with the eyepiece micrometer. It was therefore possible to calculate the approximate area and determine the number of mitoses per section and per square millimeter.

STATISTICAL METHODS

Tests for goodness of fit of observed to theoretical ratios were made by the use of χ^2 for goodness of fit. χ^2 for independence was used for testing for independence or association between the factor pair for normal versus brachytic and the factor pairs employed as testers in the different linkage groups. The corresponding P values were obtained from Fisher's (*6*) table of χ^2.

The formulae for calculating linkage intensities were obtained from the publications of Immer (*13*, *14*). The F_3 population of Colsess V × Brachytic was selected in such a manner that the method outlined by Immer (*14*) might be applied to the data.

Fisher's (*6*) t and Snedecor's (*39*) F tests were used throughout for testing the significance of differences between Brachytic and the normal strains with which it has been compared.

EXPERIMENTAL RESULTS

INHERITANCE OF THE BRACHYTIC CHARACTER

The ratio of normal to brachytic plants is presented in table 2 as a total for the two classes from the F_2 segregations of all the crosses except the F_2 of Colsess V × Brachytic. This cross has been listed separately because of the deficiency of normal types, later shown to be the result of a deficiency of chlorina types among the normal plants. The brachytic character is undoubtedly inherited as a simple Mendelian recessive.

TABLE 2.—*Ratio of normal to brachytic plants in all crosses between brachytic and normal strains*

Cross	Phenotype		χ^2 for goodness of fit to a 3:1 ratio	*P*
	Normal	Brachytic		
All crosses except F_2 of Colsess V × Brachytic	11,282	3,698	0.786	0.50–0.30
Colsess V × Brachytic (F_2)	1,804	832	60.554	[1]

[1] Very small.

LINKAGE RELATIONSHIPS OF THE GENE FOR BRACHYTIC

INTERRELATIONSHIPS BETWEEN THE *Br br* FACTOR PAIR AND FACTOR PAIRS LOCATED IN THE DIFFERENT LINKAGE GROUPS

In the first five linkage groups, it was found by applying χ^2 tests for independence that the *Br br* factor pair was inherited independently of all the testers in these groups.

In the cross Colsess IV × Brachytic, it was impossible to identify the normal and brachytic plants in the $x_c\ x_c$ class. Consequently the xantha plants were grouped and the ratio obtained was compared with a theoretical 9 : 3 : 4 ratio. The ratio obtained was 1,381 *Br* X_c : 469 *br* X_c : 476—x_c (*Br* x_c or *br* x_c) as compared to the expected ratio of 1,308.37 : 436.13 : 581.50, giving a χ^2 value of 25.649 and a *P* value of less than 0.01. It was noted in taking the data on seedlings, however, that the xantha seedlings were very weak and that many of them might have failed to emerge. Consequently, a deficiency in the xantha class might be expected. When the first two classes were tested to a 3 : 1 ratio, a χ^2 value of 0.122 with a corresponding *P* value of 0.80–0.70 was obtained, indicating that these two classes were occurring in the proportions expected on the basis of independent inheritance.

Chlorina ($f_c\ f_c$) plants usually survive and produce seed, but are considerably weaker than normal green plants. Furthermore, it is possible to distinguish between the normal and brachytic phenotypes within the chlorina class as shown in figures 5 and 6. The results from the cross between Colsess V and Brachytic are presented in table 3. The X^2 values obtained strongly suggest linkage between *Br br* and $F_c\ f_c$ in the seventh linkage group.

ESTIMATING THE LINKAGE INTENSITY BETWEEN *Br br* AND $F_c\ f_c$

The cross-over value from the F_2 data was calculated by the product method, Immer's tables (*13*) being used. Substituting the values from the F_2 in table 3 in the formula for the product method, a cross-over value of 30.8 ± 1.8 percent was obtained.

TABLE 3.—*F_2 segregation from the cross of normal chlorina (Br Br $f_c\ f_c$) × brachytic green (br br $F_c\ F_c$)*

Linkage group	Cross	F_2 ratio				χ^2 for independence	
		Br F_c	*Br* f_c	*br* F_c	*br* f_c	χ^2	*P*
VII	Colsess V × Brachytic	1,291	513	759	73	127.583	Very small.
	Do.[1]	4,559	2,003	2,201	18	825.591	Do.

[1] Within "doubly heterozygous" F_3 lines.

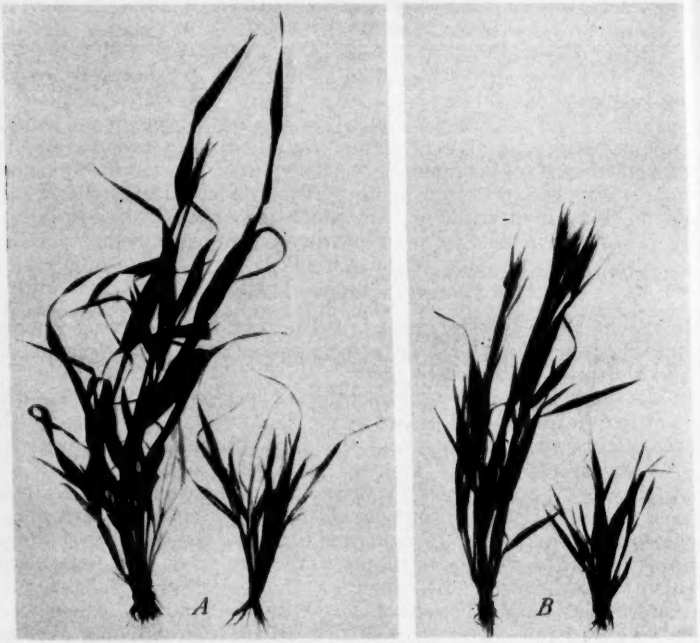

FIGURE 5.—*A*, Colsess V (normal chlorina); *B*, Brachytic (brachytic green).

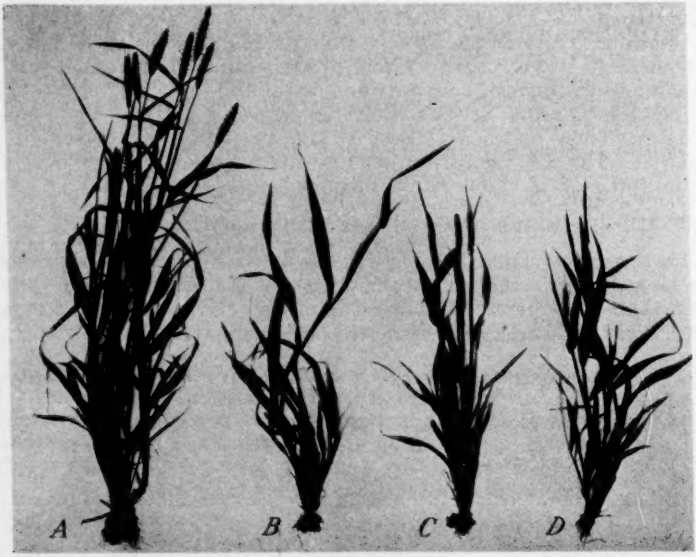

FIGURE 6.—F_3 segregates from the cross Colsess V × Brachytic: *A*, Normal green; *B*, normal chlorina; *C*, brachytic green; *D*, brachytic chlorina.

The agreement between the observed and the expected frequencies on the basis of 30.8 percent crossing over is very poor as would be expected because of the excess of brachytic types and the deficiency of chlorina types. As has been pointed out, the drought may have been responsible for a more pronounced differential germination and emergence, the chlorina types being weaker and more susceptible to the drought. Evidence on this point is available from a comparison of the percent emergence in $F_c F_c$ with that of $f_c f_c$ F_3 lines, where the emergence percentages were 76.0 and 63.9, respectively. Since f_c is linked with *Br*, a deficiency of chlorina types would decrease the proportion of normal types to a greater extent than the proportion of brachytic types. The classification for *Br* and *br* phenotypes was made in the field before the plants headed; consequently, normal plants presenting a dwarfed appearance as a result of the drought might have been classified as brachytic. Mistakes of this type were occasionally encountered when the F_2 plants, saved for seed for the F_3, were reclassified on the basis of the length of spike and awn, which is the most reliable criterion for determining the brachytic types. Other than indicating a decided linkage, the F_2 data probably do not give a very accurate cross-over value.

Of the 130 F_3 lines grown, 116 could be definitely classified according to the genotypes of the F_2 plants from which they arose. In the other 14 lines, the number of plants per line was too small to definitely establish the F_2 genotype. The minimum number of plants for accepting a line as homozygous or heterozygous was established at 12 by the χ^2 method, since only once in about 22 times would all 12 plants be of the dominant type if they arose from a heterozygous F_2 plant. Where segregation for at least three of the phenotypes occurred, the line was classified as a double heterozygote, regardless of the number of plants.

The distribution of the 116 F_3 lines is presented in table 4. Since none of the double recessives was planted, no F_3 lines appear in the last class. The separation of the *Br br* $F_c f_c$ types into those originating from coupling and those originating from repulsion was made by using Immer's (*14*) formula for determining the midpoint p'. The figures in the last column again reflect the deficiency of chlorina types which were obtained in the F^2 results.

TABLE 4.—*Distribution of the F_3 lines according to the genotypes of the F_2 parental plants*

F_3 genotypes	$F_c F_c$	$F_c f_c$	$f_c f_c$
Br Br	1	3	6
Br br	5	0 (coupling) 71 (repulsion)	0
br br	29	1	

An analysis of the F_3 data was made according to the method described by Immer (*14*). A summary of the analysis of the linkage relationships between *br* and F_c in the cross *br br* $F_c F_c \times$ *Br Br* $f_c f_c$ as determined from F_3 data follows.

F_3 genotypes	Cross-over value (per cent)
Doubly dominant	6. 48±2. 03
Double heterozygotes	. 00
Singly dominant (*Br* f_c phenotypes)	. 00
Singly dominant (*br* F_c phenotypes)	1. 69±1. 69
Within double heterozygotes (F_2 segregation)	9. 55±1. 06
Combination of classes	9. 27±0. 90

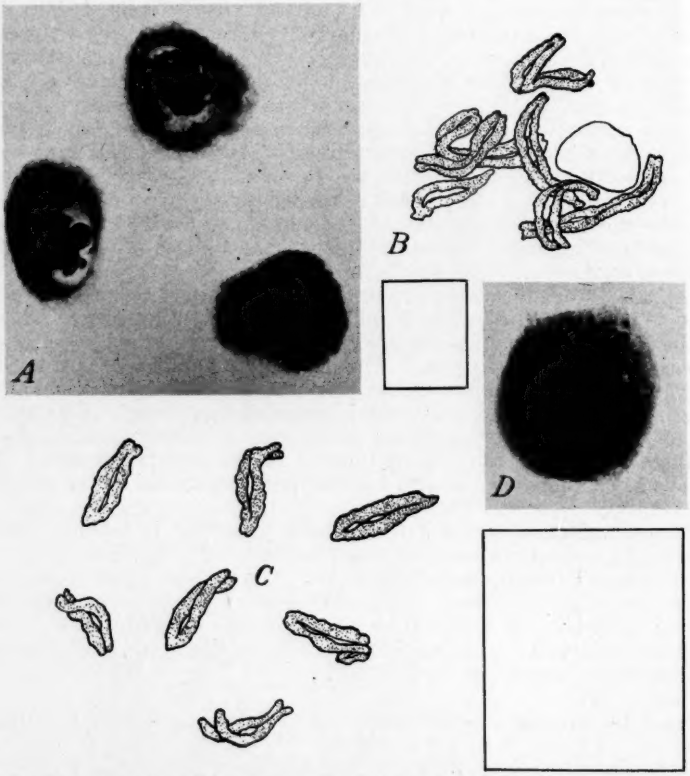

FIGURE 7.—*A*, Late pachynema in F_1 plant of Brachytic × Himalaya, × 1,125; *B*, chromosomes in late diplonema in F_1 plant of Brachytic × Himalaya, × 3,500; *C*, chromosomes in diakinesis in F_1 plant of B4 × Brachytic, × 3,500; *D*, microsporocyte showing bivalent (or ring?) off the equatorial plate in F_1 plant of Brachytic × Himalaya, × 1,695.

Because of the absence of F_3 lines from the F_2 coupling phase among the "double heterozygotes" and of *Br br* f_c f_c genotypes among the "singly dominants," zero cross-over values were obtained for the second and third classes. The fifth class may be considered as an F_2 segregation since all of the lines originated from F_2 plants in the repulsion phase. In combining all of the classes, the F_2 data were omitted because of the large discrepancies noted previously. The final cross-over value of 9.27±0.90 percent, obtained by combining all of the

F_3 data, is the best estimate available for the linkage intensity from the F_3 repulsion data used in this study.

COMPARISON OF CHROMOSOME BEHAVIOR AND NUMBER IN BRACHYTIC AND NORMAL STRAINS OF BARLEY

A study of the early and midprophase stages in barley is rendered extremely difficult by the large amount of chromatin material contained in the nucleus and by the very small sporocytes. The chromonemata are entangled in a dense mass in late pachynema and early diplonema (fig. 7, *A*); consequently, with the technique employed, it was impossible to separate the individual pairs earlier than late diplonema or early diakinesis (fig. 7, *B*, *C*). At these stages it is difficult to obtain an accurate comparison of length between paired chromosomes, although marked differences could no doubt be detected. Further, the different pairs are indistinguishable by ordinary observation in the prophase and cannot be identified separately (fig. 7, *A*, *B*, *C*). It

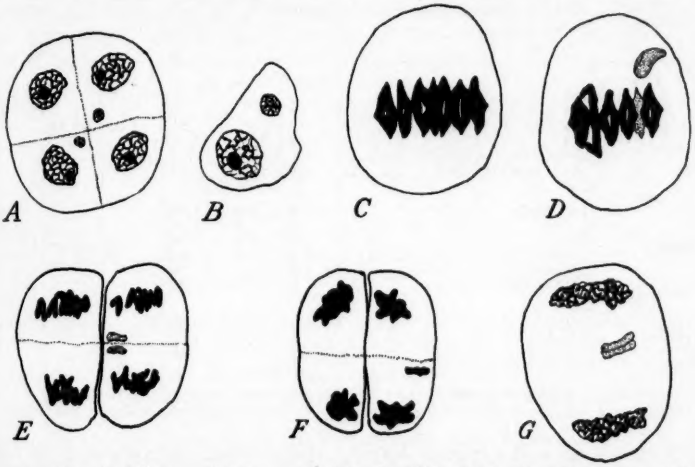

FIGURE 8.—*A*, Micronuclei in a quartet of a B4 plant; *B*, microspore with a micronucleus in F_1 plant of Brachytic × Himalaya; *C*, normal metaphase in Brachytic; *D*, nonorientation of a bivalent in Himalaya; *E*, lagging univalent undergoing a secondary split in B4; *F* and *G*, lagging univalents in B4. In *F*, one of the halves evidently has gone to one of the poles. All × 2,000.

therefore was necessary to make a general examination of each prophase for abnormal configurations and discrepancies in length between paired chromatids. In making these examinations, the different types of configuration noted by McClintock (*24*) were kept constantly in mind.

From 100 to 200 microsporocytes in the stages from pachynema to diakinesis were examined in each of the three F_1 plants of B4 × Brachytic and in the F_1 plant of Brachytic × Himalaya. No abnormal configurations or discrepancies in length between synapsed members of a pair were observed. However, in material of this nature, failure to observe such abnormalities does not establish the absence of observable chromosome changes but merely indicates that no gross changes have occurred (fig. 7, *B*, *C*).

From table 5 it may be seen that in 1932 the frequency of occurrence of micronuclei (fig. 8, *A*, *B*) in Brachytic was significantly lower than

in B4. The F_3 lines all were lower in micronuclei than either of the parents, although not significantly different from Brachytic. The percent frequency of micronuclei in the three F_1 plants also was lower than in the parents. There appears to be a tendency toward greater stability in the germ plasm of the hybrids than in the two varieties themselves.

The selections for high and low frequency of micronuclei from plants of B4 and Brachytic grown in 1932 appeared to be different in 1933 although the difference could not be established statistically. No effect of selection was observable in 1934 between the high and low selections from B4 plants grown in 1933.

TABLE 5.—*Comparison of frequency of micronuclei in different strains and hybrids of barley, 1932–34*

Year and classification	Variety or line	Plants	Micronuclei in mother plant	Micronuclei in progeny	Degrees of freedom [1]	*F*	Range
1932		*Number*	*Percent*	*Percent*			
F_1	B4 × Brachytic (*brbr*)	16	----	0.66	4, 78	[2] 5.43	0.00–4.90
	B4 × Brachytic (*Brbr*)	20	----	.19			.00–0.70
	B4 × Brachytic (*BrBr*)	20	----	.25			.00–1.20
Parent	B4	12	----	1.46			.20–5.90
	Brachytic	15	----	.82			.30–2.10
F_1	B4 × Brachytic	3	----	.10			.10–0.20
1933							
Parent	Brachytic	9	2.10	1.48	5, 45	1.03	.50–3.40
	do	9	.30	1.38			.50–2.90
	B4	10	5.90	2.04			.20–11.00
	do	6	.20	.85			.40–1.50
	Brachytic	9	----	.53			.00–1.90
	Himalaya	8	----	.85			.00–2.40
1934							
Parent	B4	12	11.00	1.03	1, 21	.42	.30–4.10
	do	11	.40	1.31			.40–4.00
F_1	Brachytic × Himalaya	1	----	.40	----	----	----

[1] The number of degrees of freedom for the variety or line and error mean squares, respectively.
[2] $P < 0.01$. 2 times the standard error of a difference between any 2 varieties or lines = 0.58 percent.

A check on a few plants having stages from metaphase I to telophase II revealed that irregularities similar to some of those occurring in wheat *(27)* were occasionally present. Metaphase I was nearly always of the regular type with seven bivalents uniformly distributed on the equatorial plate (fig. 8, *C*). In about 50 percent of the metaphase configurations, an open bivalent consisting of two equal members was observable (fig. 8, *D*). Whether the same pair is always involved was not definitely determined, although it appeared that the members of the open bivalent possessed a subterminal or submedian spindle attachment.

The various abnormalities shown in figure 8, *E*, *F*, *G*, were found to occur in all varieties and lines studied. Lagging univalents of the types shown appeared to be developing into micronuclei. Evidence of this is available from figures like those in figure 8, *F*, *G*, where chromosomes were sometimes in the process of rounding up into micronuclei after the remaining chromosomes had already been resolved into definite nuclei. The relation of other chromosome abnormalities to the occurrence of micronuclei was not determined, although in some

anthers, usually at one end or near the tapetal cells, very decided disturbances in chromosome behavior were occurring and giving rise to microspores with several micronuclei. The nonoriented bivalent or ring shown in figure 7, *D*, was found in the F_1 plant of Brachytic × Himalaya as the only one of its kind among several hundred metaphases which were observed.

The abnormalities which have been described occur very infrequently, even in plants having high percentages of micronuclei. It would seem that in a monoploid species like barley, the loss of a chromosome would result in nonfunctional spores which would constantly be eliminated. It is therefore very doubtful whether plants lacking in a chromosome or a part of a chromosome can survive unless the part lost were very small or of an inert nature.

During the course of these studies, the chromosome numbers of Brachytic and Himalaya were checked whenever a suitable cell in metaphase I was available. The somatic numbers also were checked in the root tips used for comparing cell size and number of mitoses. In no case were deviations from the normal number of 7 pairs or 14 somatic chromosomes found (fig. 8, *C*, and fig. 9).

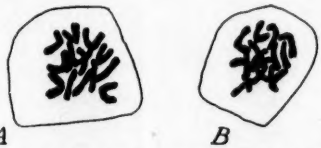

FIGURE 9.—Diploid chromosome configurations of Himalaya (*A*) and Brachytic (*B*), drawn from root tips. × 2,000.

The genetic and cytologic behavior of Brachytic leads to the conclusion that the brachytic character is perhaps the result of a gene mutation, although the possibility of a minute loss or rearrangement of a part of a chromosome should not be overlooked. An extreme rearrangement such as the inversion described by Schultz and Dobzhansky (*33*) in Drosophila could no doubt have been detected in the F_1 plants of brachytic × normal. The "position effect" resulting from a minute alteration in the chromosome as found by Muller (*3*) offers some possibility. For the present discussion, however, the assumption of a gene mutation will be used as a basis.

NATURE OF THE ACTION OF THE GENE FOR BRACHYTIC AS DETERMINED FROM COMPARISONS OF HIMALAYA AND BRACHYTIC

The general appearance of Himalaya and Brachytic already has been shown (fig. 1). In the comparisons which follow, an attempt has been made to compare by actual measurements some of the morphological, anatomical, and cytological characters of the two strains.

Comparative Gross Morphology

Typical spikes and caryopses of Himalaya and Brachytic are shown in figure 10. It will be noted that the difference in length of awns and size of caryopses is much more pronounced than the difference in length of spikes.

Comparative measurements of the two strains are presented in table 6. It is apparent that there has been a general diminution in size of the different parts of Brachytic as compared with Himalaya. Although no significant difference was obtained for weight of seed in the two samples which were compared, the writer is of the opinion that Himalaya would significantly outyield Brachytic if larger numbers were used.

The question arises as to the manner in which the brachytic gene produces the diminution in size as evidenced in the above comparisons. Possibly differences in cell size, cell number, rate of growth, or frequency of cell division might be determined as a means of explaining the differences in size of plants between the two strains.

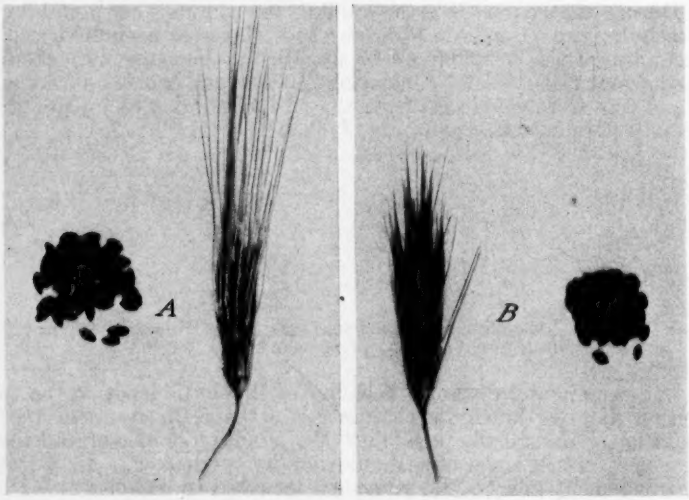

FIGURE 10.—Comparison of spikes and caryopses of Himalaya (*A*) and Brachytic (*B*). × 50.

TABLE 6.—*Quantitative comparison of different parts of Himalaya and Brachytic*

Gross morphological character	Himalaya	Brachytic	Difference in favor of Himalaya	Degrees of freedom	*t*	Brachytic in percent of Himalaya
Height up to tip of upper leaf [1] ..... centimeters	65.00	42.70	22.30	8	[2] 8.04	65.69
Height up to base of spike [1] ..... do	50.70	34.64	16.06	8	[3] 5.36	68.32
Distance between ligules [1] ..... do	5.46	4.14	1.32	8	[3] 2.74	75.82
Length of leaves [1] ..... do	22.36	14.98	7.38	8	[2] 11.35	66.99
Length of awns [4] ..... do	10.91	5.70	5.21	48	[2] 15.86	52.29
Seeds per plant [4] ..... number	85.32	92.40	−7.08	48	.60	108.30
Weight of seeds [4] ..... grams	3.07	2.92	.15	48	.33	95.18
Weight per seed [4] ..... milligrams	36.76	31.36	5.40	48	[3] 4.20	85.31

[1] 5 plants of each variety as recorded at time of heading, June 20, 1933.
[2] $P < 0.01$.
[3] $P < 0.05$.
[4] 25 plants of each variety, harvested in 1934.

Comparative Size of Plants, Organs, and Cells in Plants Growing in the Field

Two plants of each strain were studied in detail as shown in figure 11 and tables 7 and 8. Figure 11 was drawn to scale and reduced by photographing to the given size from the measurements presented in table 7 which are based on one plant of each strain, collected on June 20, 1933. The number of cells, both epidermal and parenchyma, is seen to be roughly proportional to the length of the plant and its parts, and cell length is the same in the two strains. This is further borne out in the results presented in table 8 which are based on two plants of each strain. The same plants were measured for diameter of culm, but no significant difference was found between the strains. Himalaya had a mean culm diameter of 0.39 cm. as compared to 0.37 cm. for Brachytic.

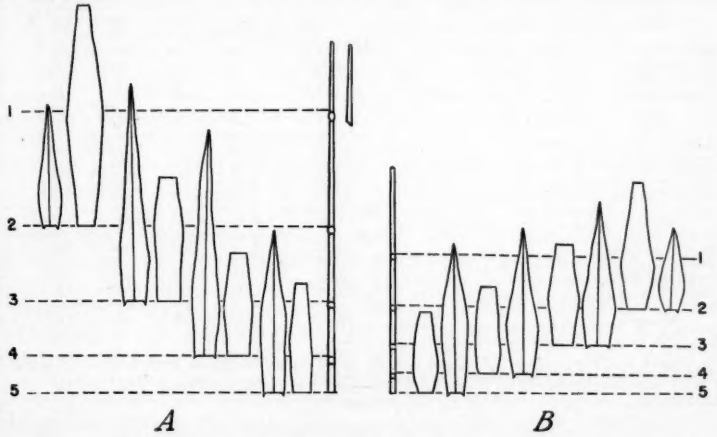

Figure 11.—Diagrammatic drawings to show relative lengths of different parts of Himalaya (*A*) and Brachytic (*B*). Numbers refer to specific parts studied: 1, first internode and node; 2, second internode and node, and first leaf sheath and blade; 3, third internode and node, and second leaf sheath and blade; 4, fourth internode and node, and third leaf sheath and blade; and 5, fifth internode and node, and fourth leaf sheath and blade. × 0.20.

Eight pairs of comparable leaves were studied for length and width of leaves, and length and width of epidermal cells. The results presented in table 9 show that the differences in cell size between varieties were not statistically significant. It was noted in the analyses of variance which were calculated that cell length, cell width, and cell shape index (length/width) varied significantly between different regions of the leaf. These comparisons are presented in table 10. The cells are longer and narrower in the terminal region and shorter and wider in the basal region, the middle region being intermediate. Cell shape also varied significantly between leaves, the older leaves having longer and narrower cells. There evidently is some correlation between cell shape and shape of different parts of the leaf and between cell shape and age of leaf.

Apparently the brachytic gene has not affected cell size in mature plants. Although the number of plants compared is very small, the

pronounced difference in size between Himalaya and Brachytic and the use of comparable plants appear to justify the comparisons which have been made.

TABLE 7.—*Comparison of length, and number and length of epidermal cells in different parts of Himalaya and Brachytic, one plant of each strain as shown in figure 11*

Part of plant	Length of parts		Cells per part		Length of cells	
	Himalaya	Brachytic	Himalaya	Brachytic	Himalaya	Brachytic
	Centimeters	*Centimeters*	*Number*	*Number*	*μ*	*μ*
First internode	17.41	9.27	1,454	768	120	121
Second internode	11.88	5.10	995	420	119	121
Third internode	7.72	3.89	661	320	117	122
Fourth internode	5.95	2.48	470	207	127	120
Fifth internode	3.31	1.70	271	145	122	117
Mean	9.25	4.49	770	372	121	120
First node	.48	.45	58	48	83	94
Second node	.49	.45	60	51	82	88
Third node	.49	.49	60	61	82	80
Fourth node	.45	.40	53	48	85	83
Mean	.48	.45	58	52	83	86
First leaf sheath	23.95	14.61	1,844	1,135	130	129
Second leaf sheath	13.50	10.99	1,007	833	134	132
Third leaf sheath	11.22	9.35	860	728	130	128
Fourth leaf sheath	10.70	8.76	841	676	127	130
Mean	14.84	10.95	1,138	843	130	130
First leaf blade	13.00	9.00	843	596	154	151
Second leaf blade	23.50	15.30	1,465	911	160	167
Third leaf blade	24.40	16.90	1,510	971	162	174
Fourth leaf blade	21.50	16.50	1,337	969	161	170
Mean	20.60	14.43	1,289	862	159	166

TABLE 8.—*Comparison of mean length, and mean number and length of cells in analogous parts of Himalaya and Brachytic, two plants of each strain*

Part of plant	Mean length of parts		Mean number of cells per part		Mean length of cells	
	Himalaya	Brachytic	Himalaya	Brachytic	Himalaya	Brachytic
	Centimeters	*Centimeters*	*Number*	*Number*	*μ*	*μ*
Culm (epidermal cells)	31.39	16.32	2,661	1,418	118	115
Internodes	7.48	3.73	620	311	120	120
Nodes	.42	.40	52	49	80	81
Culm (parenchyma cells)	31.39	16.32	1,810	1,002	173	163
Internodes	7.48	3.73	410	210	182	178
Nodes	.42	.40	49	46	86	87
Leaf sheaths (epidermal cells)	14.66	11.23	1,183	762	130	136
Leaves (epidermal cells)	21.55	14.99	1,749	880	159	169

TABLE 9.—*Comparison of mean length and width of leaves, and length and width of epidermal cells in Himalaya and Brachytic, eight leaves of each*

Character	Himalaya	Brachytic	Difference[1]	*t*
Length of leaves, centimeters	12.16	9.80	2.36	[2]7.00
Width of leaves, do	.56	.56		
Length of cells, μ	173.13	184.83	−11.70	1.36
Width of cells, μ	30.50	30.38	.12	.14
Cell-shape index, $\frac{\text{length}}{\text{width}}$	5.75	6.13	−.38	.99

[1] 7 degrees of freedom in each instance.
[2] $P<0.01$.

TABLE 10.—*Comparison of width of leaf, and width, length, and shape of epidermal cells in different regions of the leaf in Himalaya and Brachytic*

Character	Region of leaf			F
	Base	Middle	Terminal	
Width of leaf.....centimeter	0.61	0.84	0.23	[1] 79.25
Width of cells.....μ	31.50	30.70	29.50	[1] 10.89
Length of cells.....μ	169.90	175.80	193.30	[2] 5.23
Cell-shape index, $\frac{\text{length}}{\text{width}}$	5.38	5.70	6.78	[1] 15.33

[1] $P<0.01$. [2] $P<0.05$.

COMPARATIVE SIZE OF ORGANS AND CELLS IN THE PLUMULES AND PRIMARY ROOTS

The mean lengths of the plumules and their constituent cells are presented for 12 plants of each variety in table 11. It will be noted that cell length in the primary leaf is significantly different between the two varieties. On further examination of the analysis of variance, it was found that the entire difference could be accounted for by the middle region as shown in table 12. The segment from the middle region had been taken at the midpoint between the base and tip of the primary leaf; consequently, the middle segment of Himalaya was farther from the base than the middle segment of Brachytic and might be expected to have longer cells. Had the segments been taken at equal distances from the base in the two varieties, it is doubtful whether a difference in the cell size would have been found. Apparently the cells approach a maximum length in the terminal region, for here the two varieties are again similar. The fact that older leaves have much longer cells indicates that the maximum attained in young leaves is only of a temporary nature.

As in the plumules, the difference between Himalaya and Brachytic in length of primary roots approaches 50 percent. The comparisons in table 13 indicate that the width of the primary roots is significantly greater in Brachytic and that the difference in width is largely the result of a greater number of cells in this dimension, although there is also some indication of wider cells. Length of cells and cell shape were similar in the two varieties, although they were greatly different in the two regions.

TABLE 11.—*Comparison of length of plumules, and length of cells in coleoptiles and primary leaves of Himalaya and Brachytic, 12 plants of each variety*

Character	Himalaya	Brachytic	Difference	Degrees of freedom [1]	F
Length of plumule.....millimeters	56.25	32.42	23.83	1, 16	[2] 37.54
Length of cell in coleoptile.....μ	174.08	186.63	−12.55	1, 16	.82
Length of cell in primary leaf.....μ	34.21	29.44	4.77	1, 16	[3] 5.46

[1] 1, 16 the number of degrees of freedom for the varietal and error mean squares, respectively.
[2] $P<0.01$.
[3] $P<0.05$.

TABLE 12.—*Comparison of length of cells in microns in different regions of the primary leaves of Himalaya and Brachytic*

Leaf region	Himalaya	Brachytic	Difference	Degrees of freedom [1]	*F*
Basal	18.50	17.61	0.89	2, 61	[2] 3.61
Middle	44.04	32.56	11.48		
Terminal	40.10	38.15	1.95		

[1] The number of degrees of freedom for variety × region and error mean squares, respectively.
[2] $P < 0.01$, 2 times the standard error of a difference between varieties in any region = 6.14μ.

TABLE 13.—*Comparison of length and width, and cell size and shape in primary roots of Himalaya and Brachytic*

Character	Himalaya	Brachytic	Difference [1]	*F*
Length of primary root ..... millimeters	21.50	10.30	11.20	[2] 32.89
Width of middle region ..... do	.32	.42	−.10	[3] 7.99
Cells across middle region ..... number	10.30	12.80	−2.50	[3] 8.81
Width of cells in middle region ..... μ	30.80	33.09	−2.29	.65
Length of cells in middle region ..... μ	129.13	123.16	5.97	.10
Cell-shape index in middle region	4.33	3.91	.42	.55
Width of tip ..... millimeters	.32	.39	−.07	[2] 26.24
Cells across tip ..... number	20.30	22.30	−2.00	2.13
Width of cells in tip ..... μ	15.90	17.60	−1.70	2.57
Length of cells in tip ..... μ	26.98	29.22	−2.24	1.56
Cell-shape index in tip	1.70	1.69	.01	

[1] In all cases the number of degrees of freedom for the varietal and error mean squares are, respectively, 1 and 12.
[2] $P < 0.01$.
[3] $P < 0.05$.

From the comparison of the gradients in number of cells per field in table 14, it appears that the cells approach a constant for cell length at about the same level in the two varieties. There is, however, a tendency for Himalaya to have a larger number of cells in fields 3 and 4. This is the line between the region of cell division and the region of cell elongation. If Himalaya has a higher rate of cell division, as is shown later, it might be expected to show an accumulation of cells in this region.

The evidence from the plumules and primary roots substantiates the conclusion from plants growing in the field that cell size in Brachytic is similar to cell size in Himalaya. It would seem that the difference in plant size between Himalaya and Brachytic might be fully accounted for by a difference in cell number.

COMPARATIVE DAILY GROWTH INCREMENTS

The growth measurements taken during the period from May 20 to June 20 represented 11 successive intervals, varying in length from 2 to 6 days. The means for the five plants of each variety are presented for each interval with the total and mean daily growth increments for the entire period in table 15. As expected, the difference between varieties is consistently in favor of Himalaya except in the first interval where, apparently by chance, Brachytic has grown more than Himalaya.

Although there is a striking difference in the amount of growth from day to day, the time of differentiation of the various parts and the date of heading remain practically the same in the two varieties. This is shown in table 16, which is based on observations of comparable

rows grown in 1933. Apparently the brachytic effect is manifested only in the daily amount of growth and the total amount of growth attained. Other factors tend to produce their effects independently, regardless of the height or size of the plant.

TABLE 14.—*Comparison of cell-number gradients in root tips of Himalaya and Brachytic*

Field No.	Cells per field in—		Difference	Field No.	Cells per field in—		Difference
	Himalaya	Brachytic			Himalaya	Brachytic	
	Number	*Number*	*Number*		*Number*	*Number*	*Number*
1	27.3	26.9	0.4	7	2.4	2.7	−0.3
2	29.8	29.0	.8	8	2.1	2.8	−.7
3	21.0	14.9	6.1	9	1.8	2.5	−.7
4	9.6	6.0	3.6	10	1.8	2.2	−.4
5	4.7	3.7	1.0	11	1.7	2.1	−.4
6	3.1	3.1	.0	12	1.6	1.6	.0

TABLE 15.—*Comparison of mean daily growth increments of Himalaya and Brachytic*

Variety	Mean daily growth during intervals shown											Total growth	Mean daily growth
	May 20–22	May 23–24	May 25–30	May 31–June 1	June 2–3	June 4–5	June 6–7	June 8–10	June 11–14	June 15–17	June 18–20	May 20–June 20	May 20–June 20
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
Himalaya	0.70	2.07	1.40	1.53	2.05	2.10	1.98	1.85	1.44	2.83	2.37	56.18	1.81
Brachytic [1]	1.23	.85	1.17	1.20	.60	1.56	1.47	1.03	1.00	1.44	1.45	36.58	1.18
Difference	−.53	1.22	.23	.33	1.45	.54	.51	.82	.44	1.39	.92	19.60	.63

[1] The mean growth increment of Brachytic is 65.19 percent that of Himalaya.

TABLE 16.—*Comparison of dates of differentiation and date of heading of Himalaya and Brachytic*

Variety	Planting	Emergence	Appearance of second leaf	Appearance of third leaf	Appearance of fourth leaf	Appearance of fifth leaf	Appearance of first tiller	Heading
Himalaya	Apr. 28	May 10	May 13	May 17	May 21	May 24	May 22	June 20
Brachytic	Apr. 28	May 11	May 13	May 17	May 22	May 24	May 24	June 20

COMPARATIVE FREQUENCY OF MITOSIS

The meristematic region in the root tips of Himalaya was found to be significantly longer and narrower than that of Brachytic. The two dimensions were compensatory as far as the two varieties were concerned, for the total area per section was similar. Since cell size was not significantly different between varieties, the total number of mitoses per section was compared directly. The number of mitoses per square millimeter also was figured for each plant in order to obtain a comparison on a unit-area basis. The results are presented in table 17.

The frequency of mitosis is somewhat higher in Himalaya for both total number of mitoses per section and number per square millimeter,

indicating that the rate of cell division might be higher in Himalaya than in Brachytic. Owing to the large amount of variation within varieties, however, the difference between varieties could not be established as being statistically significant. The use of a larger number of plants would be necessary to determine this more accurately. Since cell size in the meristematic region is similar in the two varieties, it seems reasonable to assume that the critical size for cell division also is similar. Consequently, cell elongation and cell enlargement might be expected to occur at a higher rate in Himalaya to bring the cells to the critical size for division more rapidly.

TABLE 17.—*Comparison of area per section of meristematic region in root tips, and frequency of mitosis per section in Himalaya and Brachytic*

Character	Himalaya	Brachytic	Difference[1]	F
Length, millimeters	0.671	0.540	0.131	[2] 15.81
Width, do	.035	.042	−.007	[2] 13.41
Area, square millimeters	.215	.207	.008	.63
Mitoses per section, number	65.2	51.4	13.8	1.69
Mitoses per square millimeter, do	303.4	245.8	57.6	2.30

[1] In all cases the number of degrees of freedom for the varietal and error mean squares are, respectively, 1 and 12.
[2] $P<0.01$.

DISCUSSION

The small number of chromosomes in cultivated barley makes it ideal material for studies of inheritance and linkage. The fact that it is a simple diploid is good reason for believing that a large proportion of its characters will be inherited in a simple Mendelian manner. The work on barley cited in the review of literature shows rather conclusively that such is the case. Stadler (*40*, *41*) concluded from his results in inducing mutations by X-rays in diploid, tetraploid, and hexaploid species of small grains, that the lower mutation rates in polyploid species are due to the presence of duplicate or triplicate factors, all of which must mutate for at least one member of the factor pair in order that the mutation be expressed in the resulting progeny. Cultivated barley was shown to have a significantly higher mutation rate than the cultivated species of wheat and oats. It follows, therefore, that very little duplication of genes in different chromosomes is to be expected.

It is due to the work of Robertson, Deming, and Koonce (*31*) that the seventh linkage group in barley has been established. These workers have to date located two genes in this group, both of them chlorophyll abnormalities which are either lethal or lacking in survival ability when in the homozygous recessive condition. The location of genes for characters having normal survival ability in this linkage group therefore would obviate difficulties encountered when testing for the presence of other genes. The gene for brachytic should be of value in this respect since Brachytic plants have good survival ability.

From a cytogenetic standpoint, it would seem that difficulties will be encountered in attempts to correlate genetic and cytologic data for the different linkage groups in barley as has been done in *Zea* (*21*, *24*). The chromosome strands in barley are very densely interwoven in the midprophase stages and the chromosome pairs are very similar in appearance and size. It therefore is difficult to separate

and distinguish the different pairs, especially in the stages desired. Lewitsky (*19*), however, has reported that the somatic chromosomes in barley may be differentiated on the basis of precise measurements and the presence of contrictions in certain regions of the chromosome after special fixing and staining techniques are employed. Special techniques for stages of meiosis or a study of the somatic chromosomes therefore offer possibilities for cytogenetic studies in barley.

The manner in which a gene expresses itself as manifested in its effect on the mature organism is of considerable importance in determing the action or dynamics of the gene. For example, what are the intermediate steps between the immediate processes of the gene after it enters the zygote and the ultimate effects which it produces on the mature individual?

The relation of genetic factors to enzyme production has been discussed by Goldschmidt (*8*, *10*). Van Overbeek (*42*) showed that a simply inherited dwarf type of growth in corn was the result of a higher rate of destruction of growth substance (growth hormone or auxin) in the dwarf type than in the normal. It is conceivable that the difference in the amounts of growth attained in Himalaya and Brachytic may be due to a heritable difference in the amount of growth substance produced or destroyed.

Goldschmidt (*9*) has postulated genetic factors which determine the time and rate at which developmental processes occur. A comparison between Himalaya and Brachytic is of interest in this respect. Growth occurs at different rates, but differentiation and maturation occur at the same time in both varieties. The gene for the rate of growth, which may be considered a rate factor, evidently produces its effects independently of genes for differentiation which may be considered time factors. Further evidence on the independence of genes for growth and differentiation is available from the 24 F_3 lines of B4 $\times$ Brachytic. B4 was about 5 days earlier for date of heading than Brachytic in 1932; however, one homozygous brachytic F_3 line was obtained which headed 1 day earlier than any of the B4 lines and 6 days earlier than any of the Brachytic lines.

The results indicate that the organism as a whole rather than the individual cell must be considered as the fundamental unit of development. Factors for growth and differentiation seemingly act on the entire plant structure which during the course of its development becomes differentiated into cells whose number and form are determined by the size and form which the plant and its organs attain. The extent to which cells are formed seems to have no bearing on the time of differentiation and maturity; factors determining these processes evidently act on the entire protoplasmic mass, regardless of the number of cells which have been formed. This conclusion may have some bearing on the controversy between the "cell theory" and "organismal theory" which has been reviewed and discussed by Sharp (*34*) and Sinnott (*36*).

SUMMARY

A mutant character in barley, designated as brachytic, has been studied with respect to its genetic and cytologic behavior.

The gene for brachytic habit of growth behaves as a simple Mendelian recessive to the gene for normal habit of growth. It has been designated as *br*.

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The factor pair *Br br* was found to be independent of the first six linkage groups and definitely associated with F_c f_c in the seventh linkage group.

The linkage intensity between *Br br* and F_c f_c was determined from repulsion data. The cross-over value from the F_2 data was found to be 30.8 ± 1.8 percent but is not considered reliable because of a deficiency of chlorina types and possible errors in classification. The cross-over value from the F_3 data, which may be considered more reliable, was 9.27 ± 0.90 percent.

The appearance, behavior, and number of chromosomes were as regular in Brachytic as in the normal strains, Himalaya and B4. The brachytic character is not associated with any observable change in chromosome structure; more likely it is the result of a gene mutation.

There is a general diminution in size of Brachytic plants and their parts as compared to those of Himalaya, the variety from which Brachytic mutated. Brachytic grows about two-thirds as tall, its leaf sheaths are about two-thirds as long, and its awns are about one-half as long. The number of seeds per plant is about the same for the two strains but Brachytic seeds are only 85 percent as heavy. The total weight of seed per plant in Brachytic was about 95 percent of that for Himalaya but the standard error of the difference was too large to establish a significant difference.

Length of cells in comparable plants growing in the field was found to be similar in the two strains. The number of cells is proportional to length of the plant and its parts.

Epidermal cells were longer and narrower in the tip than in the middle and basal regions of the leaves. Older leaves had longer and narrower cells than younger leaves.

Although the plumules and primary roots of Himalaya were approximately twice as long as those of Brachytic, no significant differences were obtained for cell size in comparable parts.

The primary roots of Brachytic were larger in diameter than those of Himalaya, the difference being associated more strongly with number than with width of cells.

Cells in the primary leaves and primary roots increased progressively in size at increasing distances from the meristematic region. The nature of the gradient in root tips differed somewhat between strains in the region differentiating the zone of cell division and the zone of cell elongation, but cell size was found to be similar in the two strains beginning only a short distance back of this region.

Brachytic grew 65.19 percent as tall as Himalaya, the difference in daily amounts of growth remaining fairly constant between the two varieties.

Factors for differentiation and maturity appeared to act independently of the factor for rate of growth.

Himalaya had a longer and narrower meristematic region in sections of root tips than Brachytic but the total area per section was similar in both varieties.

The results indicate that Himalaya has a higher frequency of mitosis per section of meristematic region than Brachytic but this could not be established statistically. A similar relationship was found for the number of mitoses per square millimeter. The rate of cell division and elongation might be expected to be higher in Himalaya than in Brachytic.

A discussion of linkage groups and the possibility of correlating genetic and cytologic data in barley has been presented.

The relation of genetic factors to the production and utilization of growth substances, which in turn influence the rate of growth and cell elongation, has been discussed.

An explanation based on Goldschmidt's physiological theory of inheritance has been advanced to account for the independence of the gene for rate of growth and factors for differentiation and maturity.

The results indicate that cell formation is subordinate to the development of the organism as a whole.

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